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(54) **PLACEMENT OF WIRELESS REPEATERS IN A WIRELESS COMMUNICATION NETWORK**

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See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

2005/0195975	A1	9/2005	Kawakita	
2006/0268728	A1*	11/2006	Mower et al.	370/252
2007/0008889	A1*	1/2007	Seo	370/232
2007/0147338	A1*	6/2007	Chandra et al.	370/350
2007/0177581	A1	8/2007	Rodgers et al.	
2008/0057973	A1	3/2008	Park	
2008/0132166	A1*	6/2008	Park et al.	455/15
2009/0089863	A1	4/2009	Vanniarajan	
2009/0116402	A1*	5/2009	Yamasaki	370/253
2009/0168687	A1	7/2009	Li et al.	

2009/0303880	A1	12/2009	Maltz et al.
2010/0046417	A1	2/2010	Tamura
2010/0054215	A1	3/2010	Stahl et al.
2010/0128622	A1	5/2010	Horiuchi et al.

(Continued)

**FOREIGN PATENT DOCUMENTS**

CN	101562863	A	10/2009
EP	2059059	A1	5/2009

(Continued)

**OTHER PUBLICATIONS**

International Search Report and Written Opinion—PCT/US2012/028646—ISA/EPO—Sep. 20, 2012.

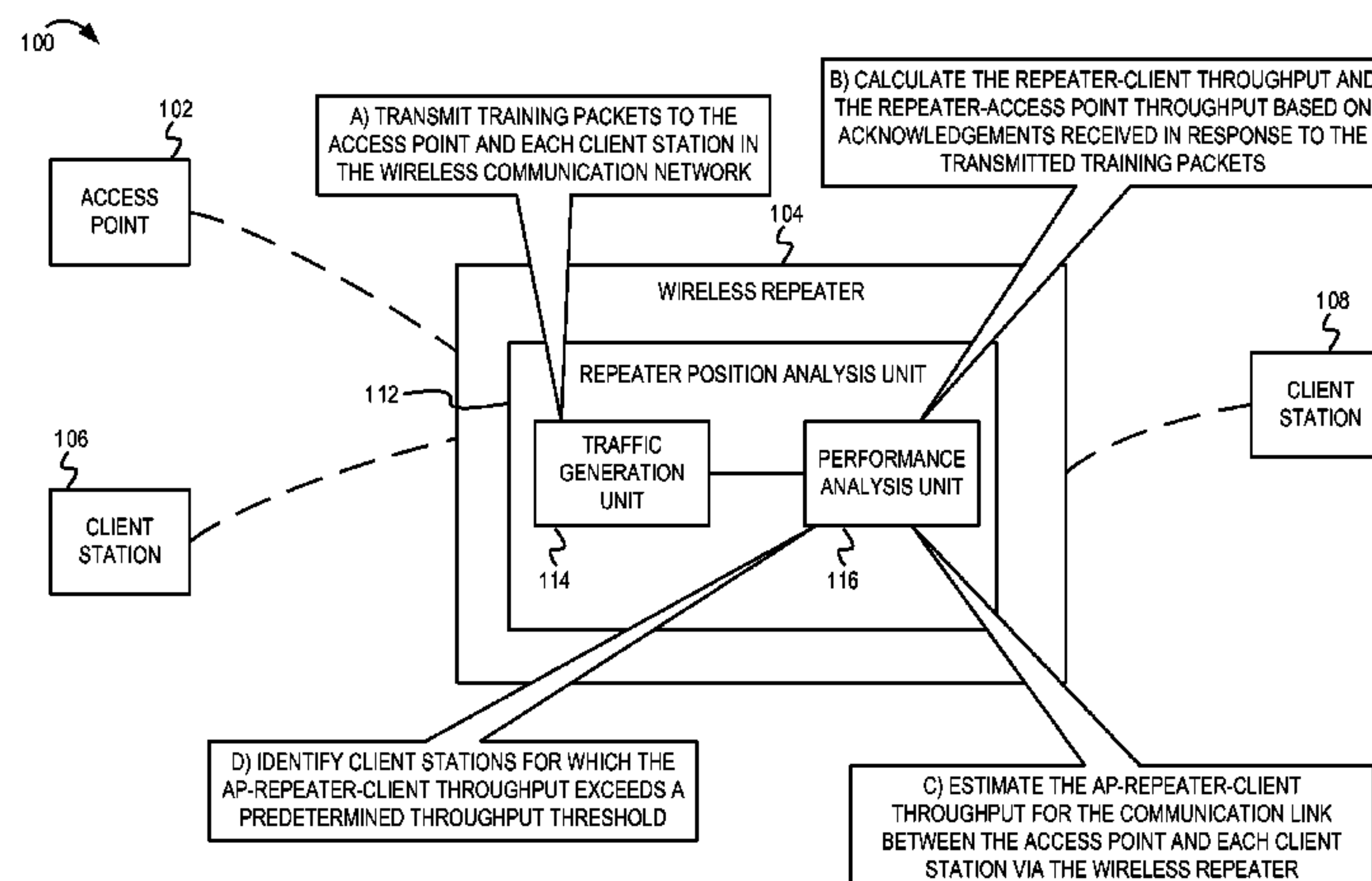
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(57) **ABSTRACT**

The position of wireless repeaters within a wireless communication network can affect the throughput and performance of the wireless communication network. A wireless repeater and/or an access point associated with the wireless communication network can be configured to determine the optimal position of the wireless repeater based on throughput achieved on communication links between the access point, the repeater, and/or the client stations. The throughput achieved on communication links between the access point, the repeater, and/or the client stations can be determined by exchanging training packets, receiving acknowledgement messages in response to the training packets, and subsequently analyzing the received acknowledgement messages. Furthermore, the throughput achieved on communication links between the access point, the repeater, and/or the client stations can also be analyzed to determine whether each of the client stations should associate with the access point or the wireless repeater.

**25 Claims, 10 Drawing Sheets**



(56)

**References Cited**

**OTHER PUBLICATIONS**

**U.S. PATENT DOCUMENTS**

2011/0007692 A1 1/2011 Seok  
2011/0029664 A1 2/2011 Harrang et al.  
2011/0110345 A1\* 5/2011 Heidari et al. .... 370/338  
2011/0199919 A1\* 8/2011 Lin et al. .... 370/252  
2012/0057462 A1 3/2012 Kotecha et al.  
2012/0215834 A1 8/2012 Chen et al.  
2012/0271902 A1 10/2012 Baliga et al.

**FOREIGN PATENT DOCUMENTS**

WO 2010045971 A1 4/2010  
WO 2012122366 9/2012  
WO 2012122550 9/2012  
WO 2012145560 10/2012

International Search Report and Written Opinion—PCT/US2012/034322—ISA/EPO—Sep. 14, 2012.  
Partial International Search Report—PCT/US2012/028646—ISA/EPO—Jun. 12, 2012.  
“U.S. Appl. No. 13/090,784 Final Office Action”, Jul. 23, 2013 , 16 pages.  
“PCT Application No. PCT/US2012/028646 International Preliminary Report on Patentability”, Apr. 18, 2013, 11 pages.  
“PCT Application No. PCT/US2012/034322 International Preliminary Report on Patentability”, Mar. 27, 2013, 9 pages.  
“PCT/US2012/028646 Written Opinion of the International Preliminary Examining Authority”, Feb. 7, 2013, 10 pages.  
“U.S. Appl. No. 13/090,784 Non Final Office Action”, Dec. 7, 2012 , 14 Pages.

\* cited by examiner

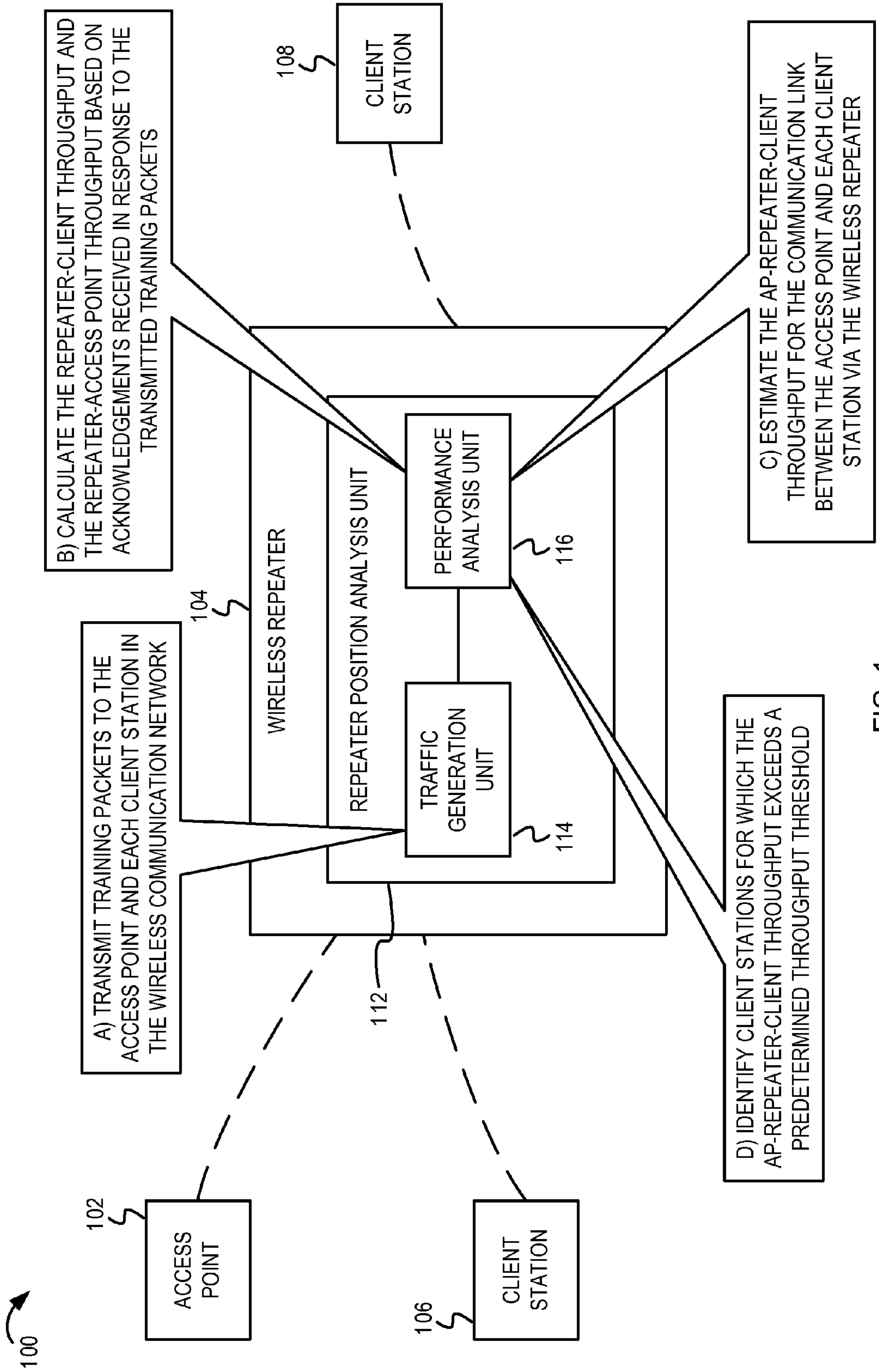
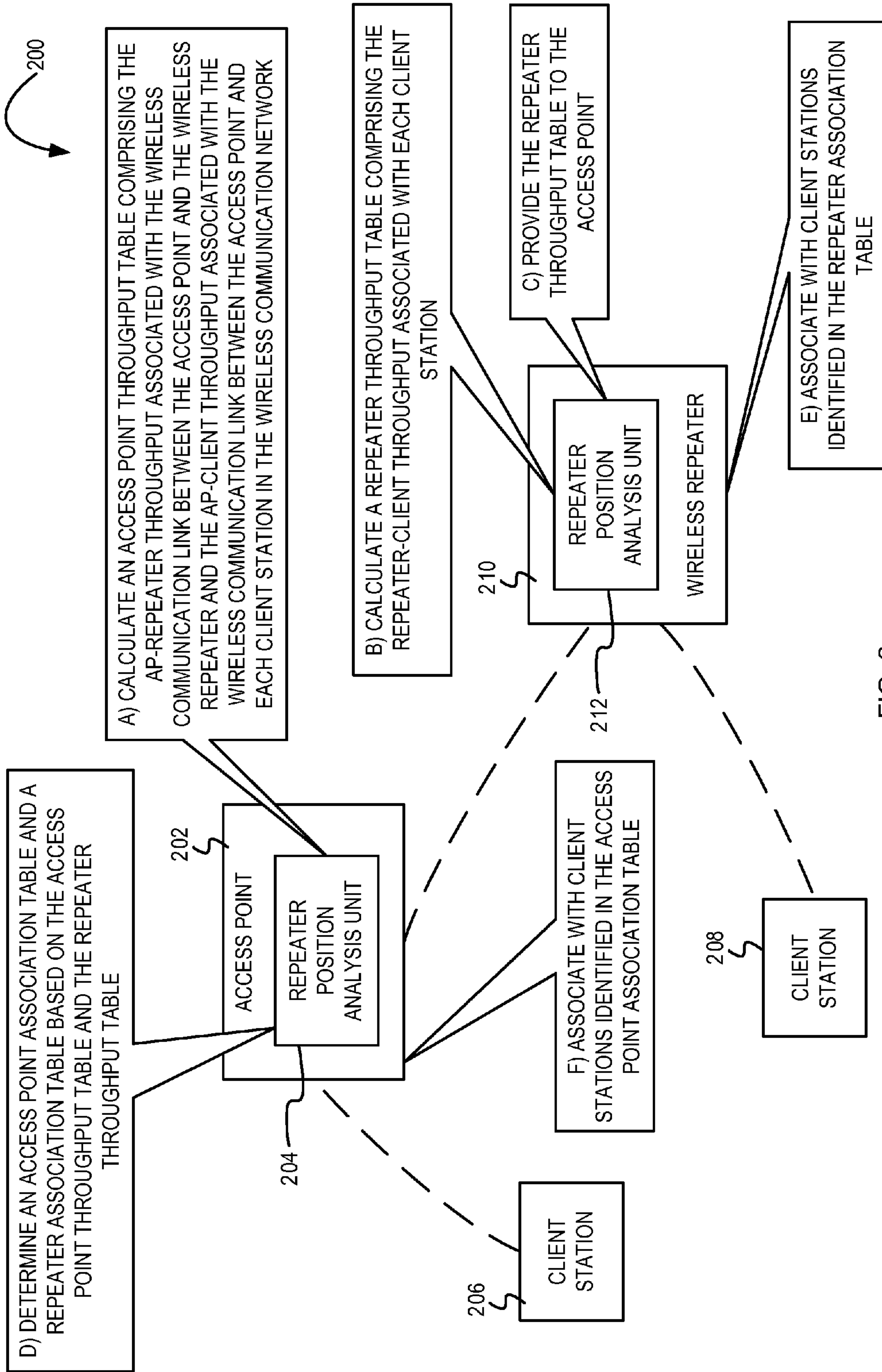


FIG. 1





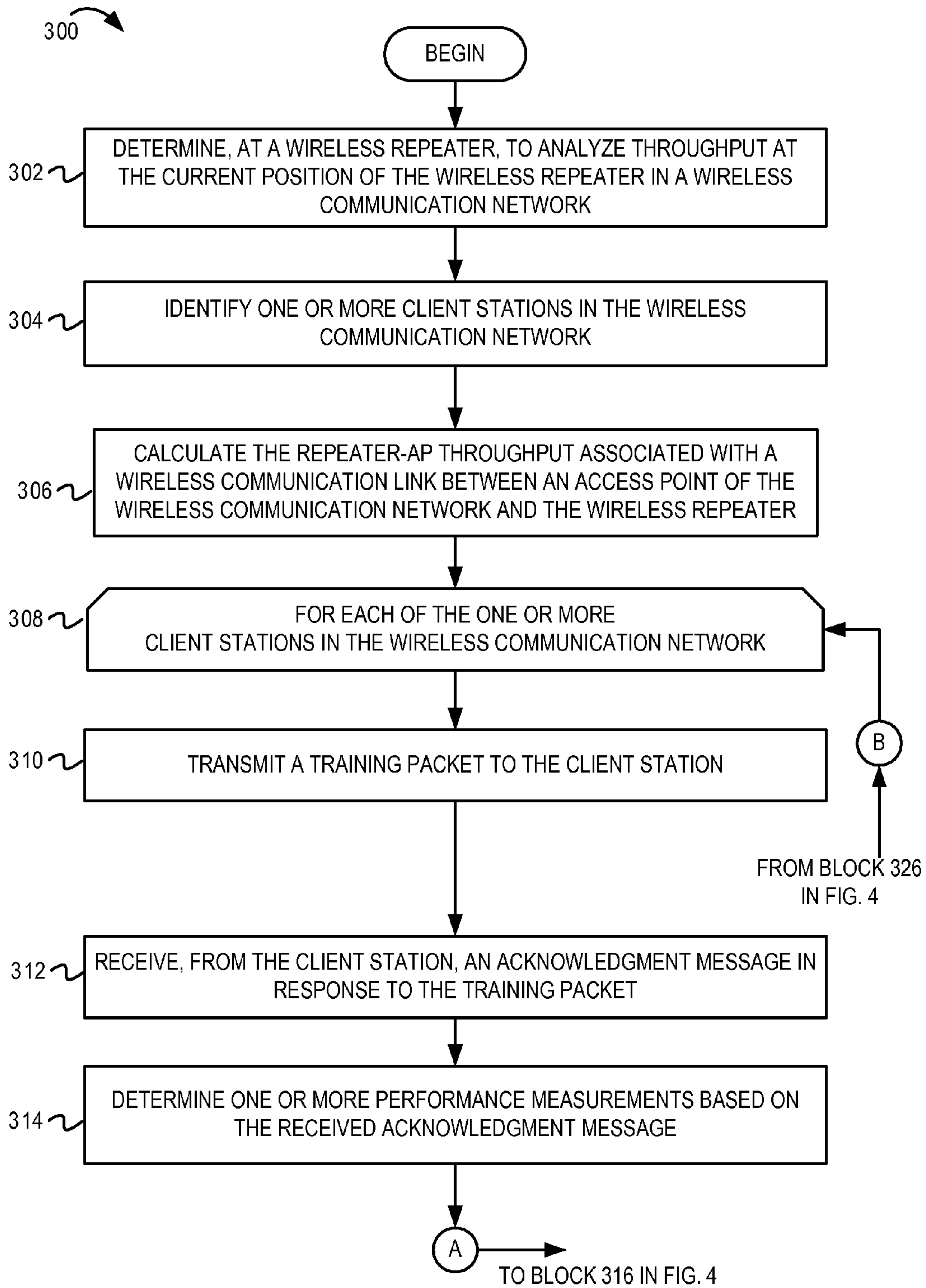
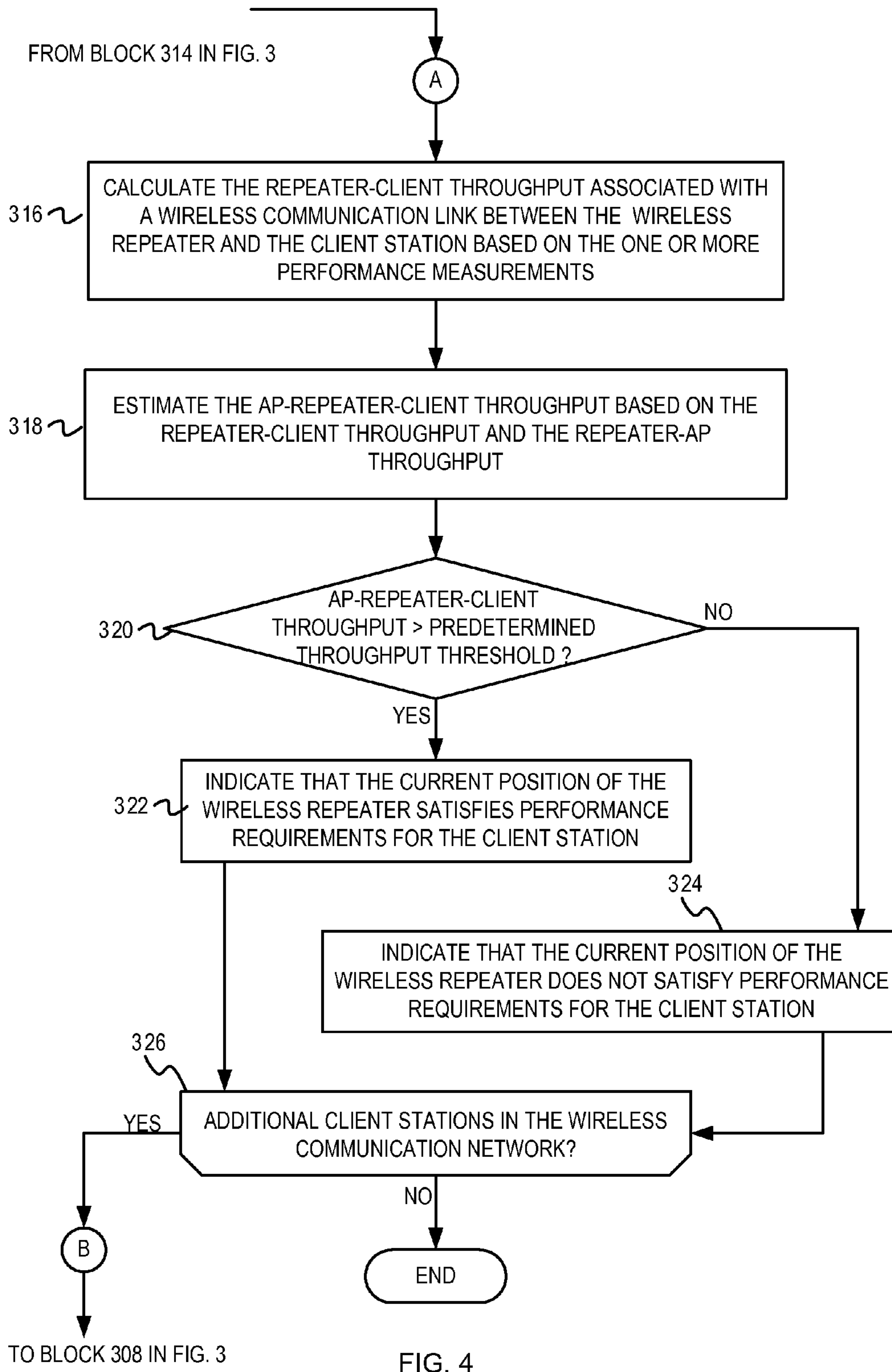
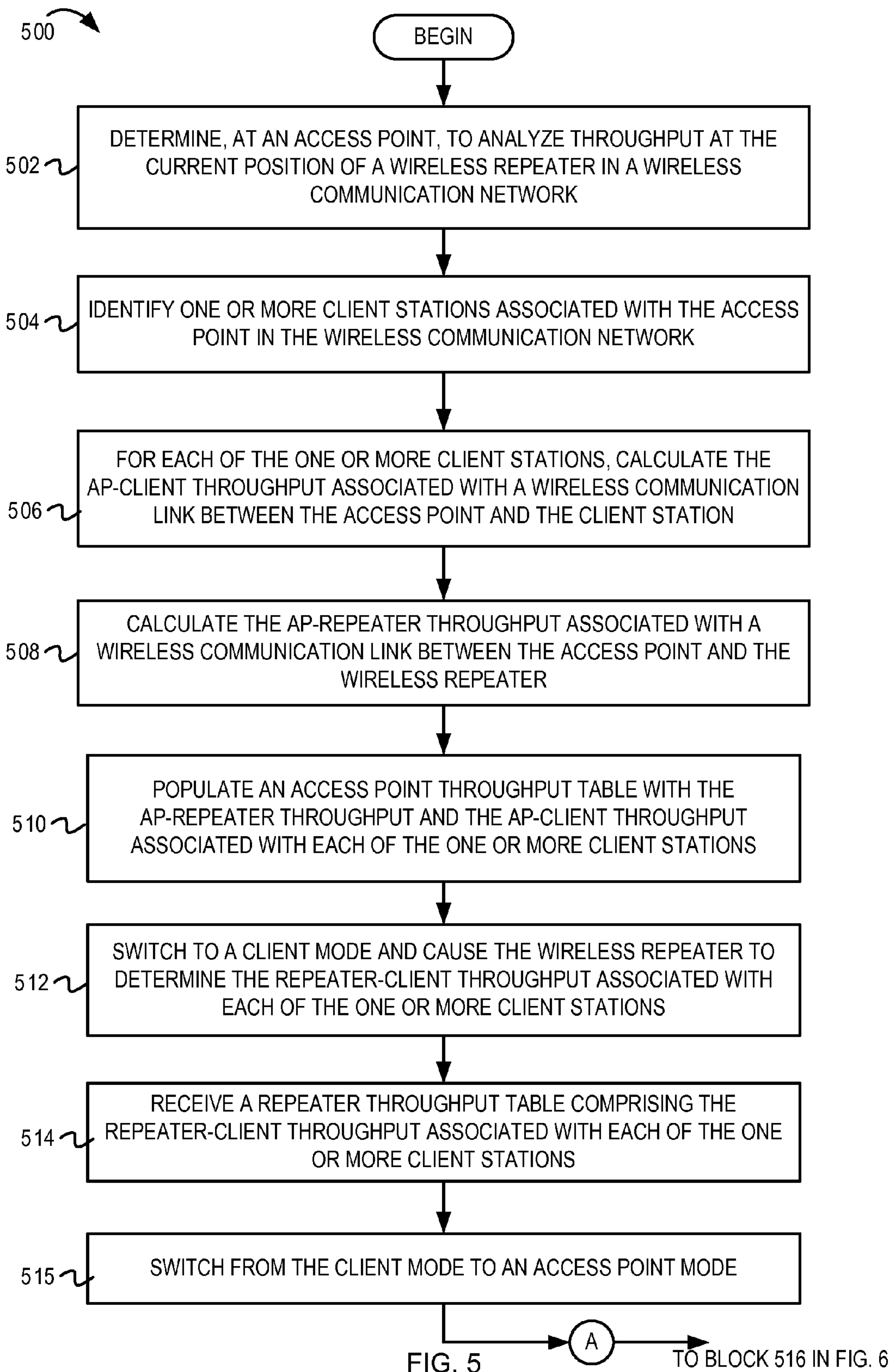
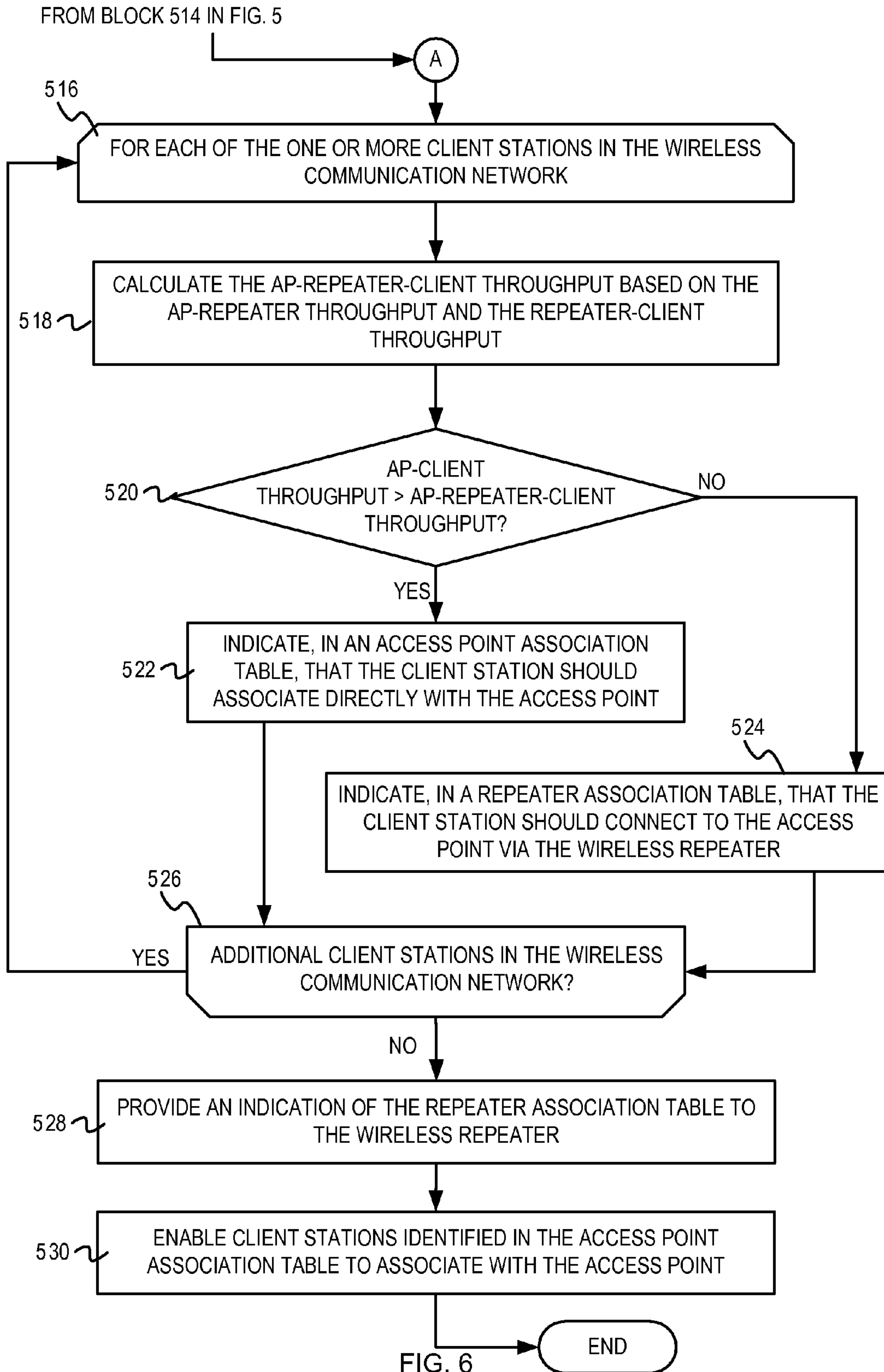


FIG. 3









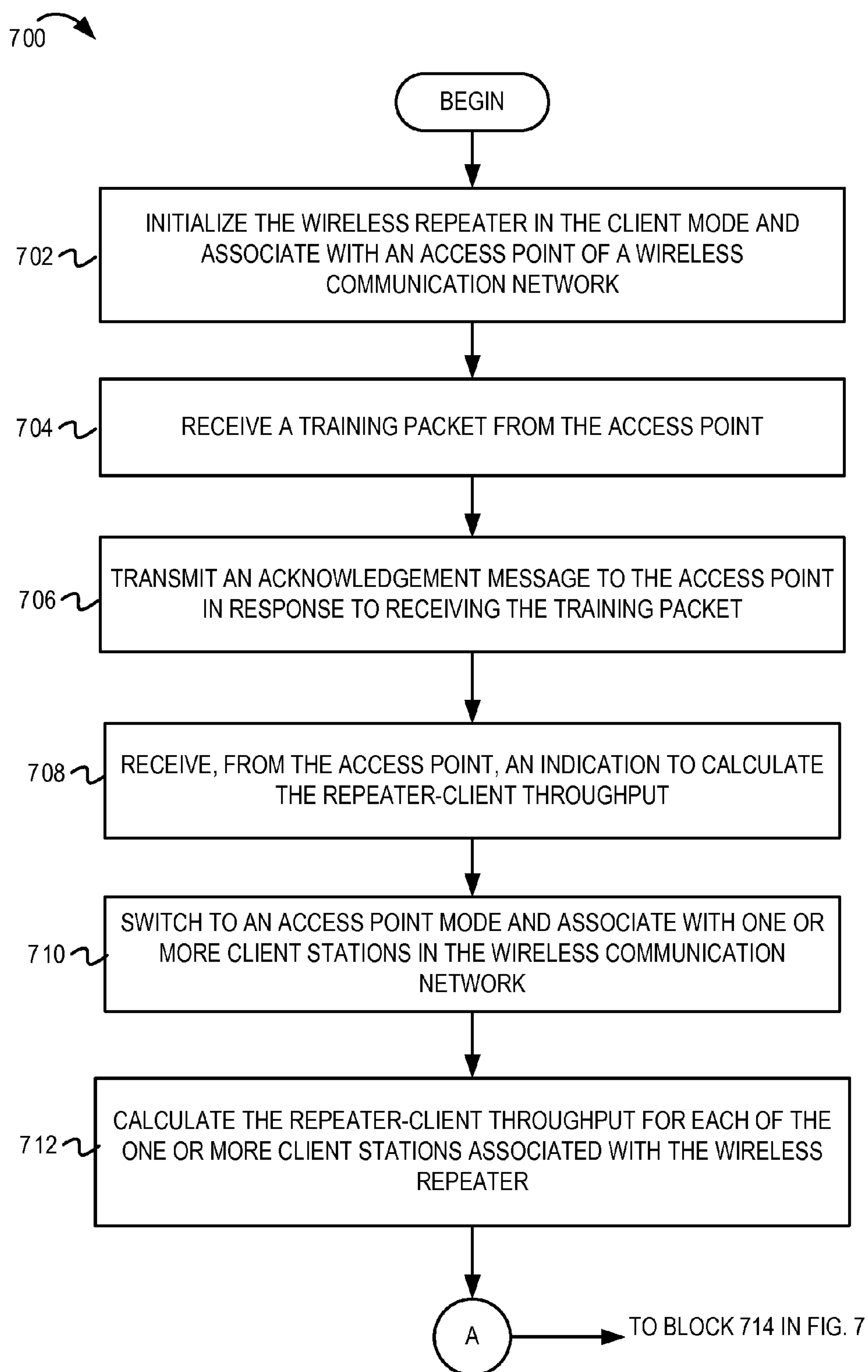


FIG. 7

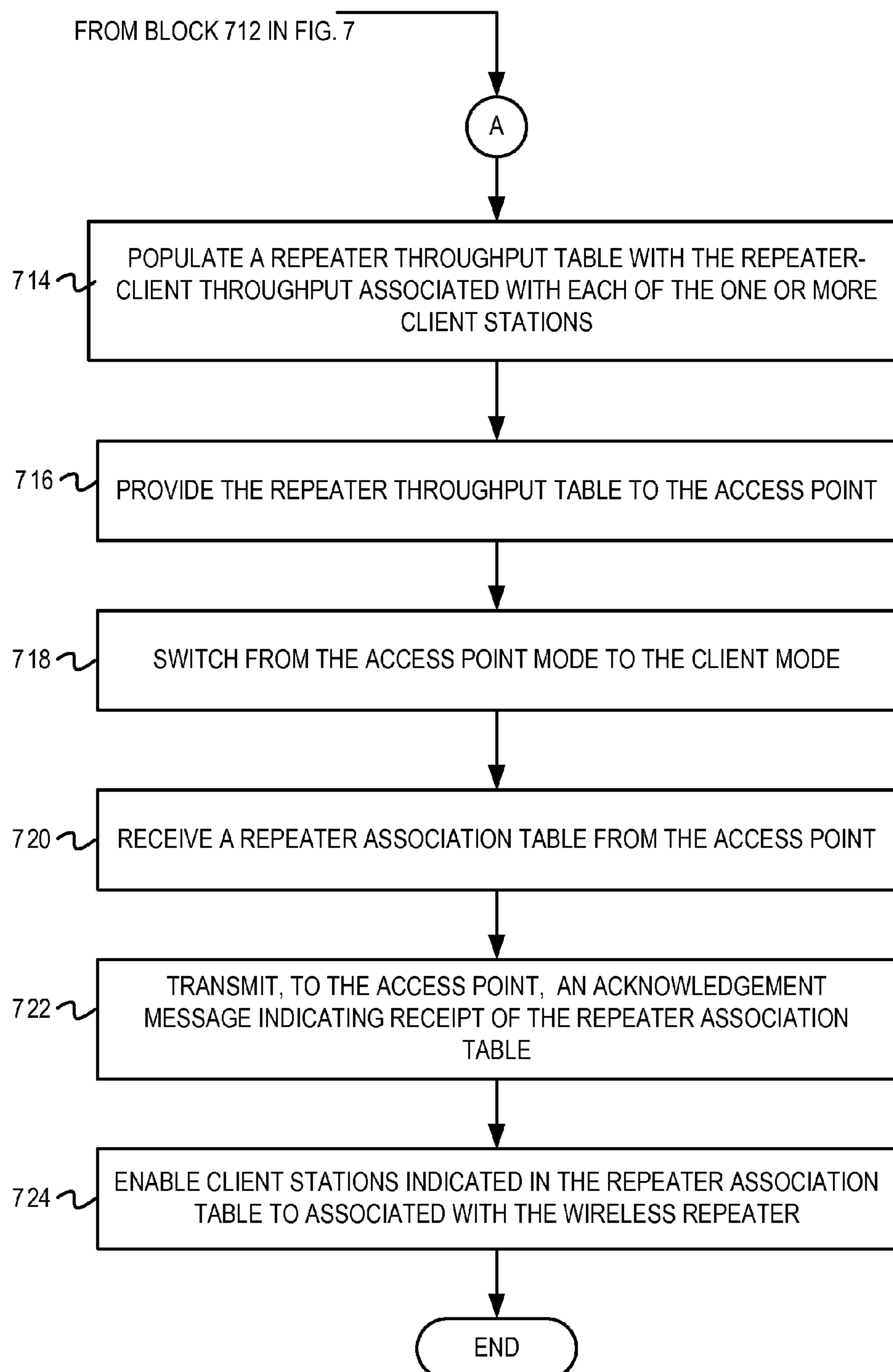


FIG. 8

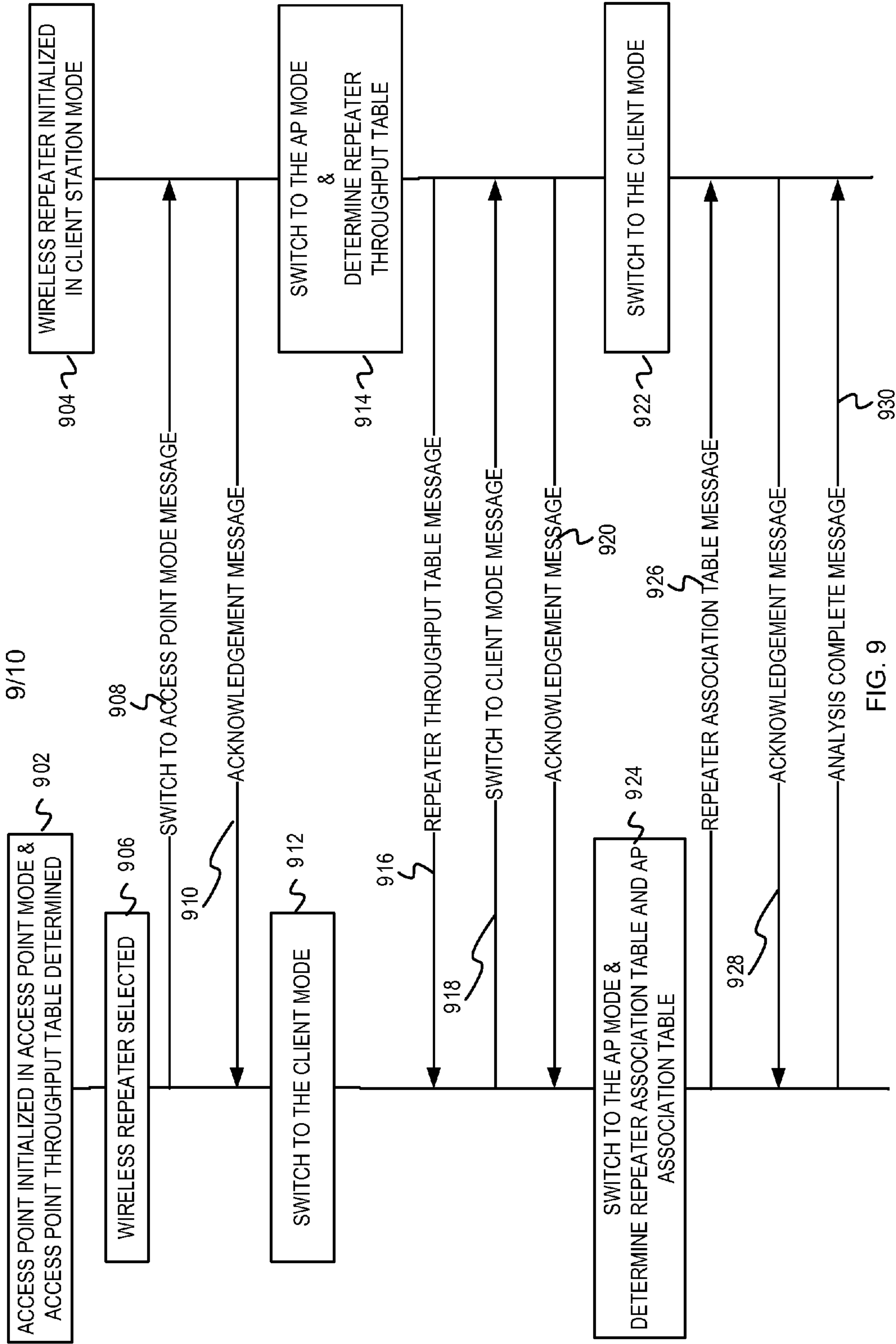


FIG. 9

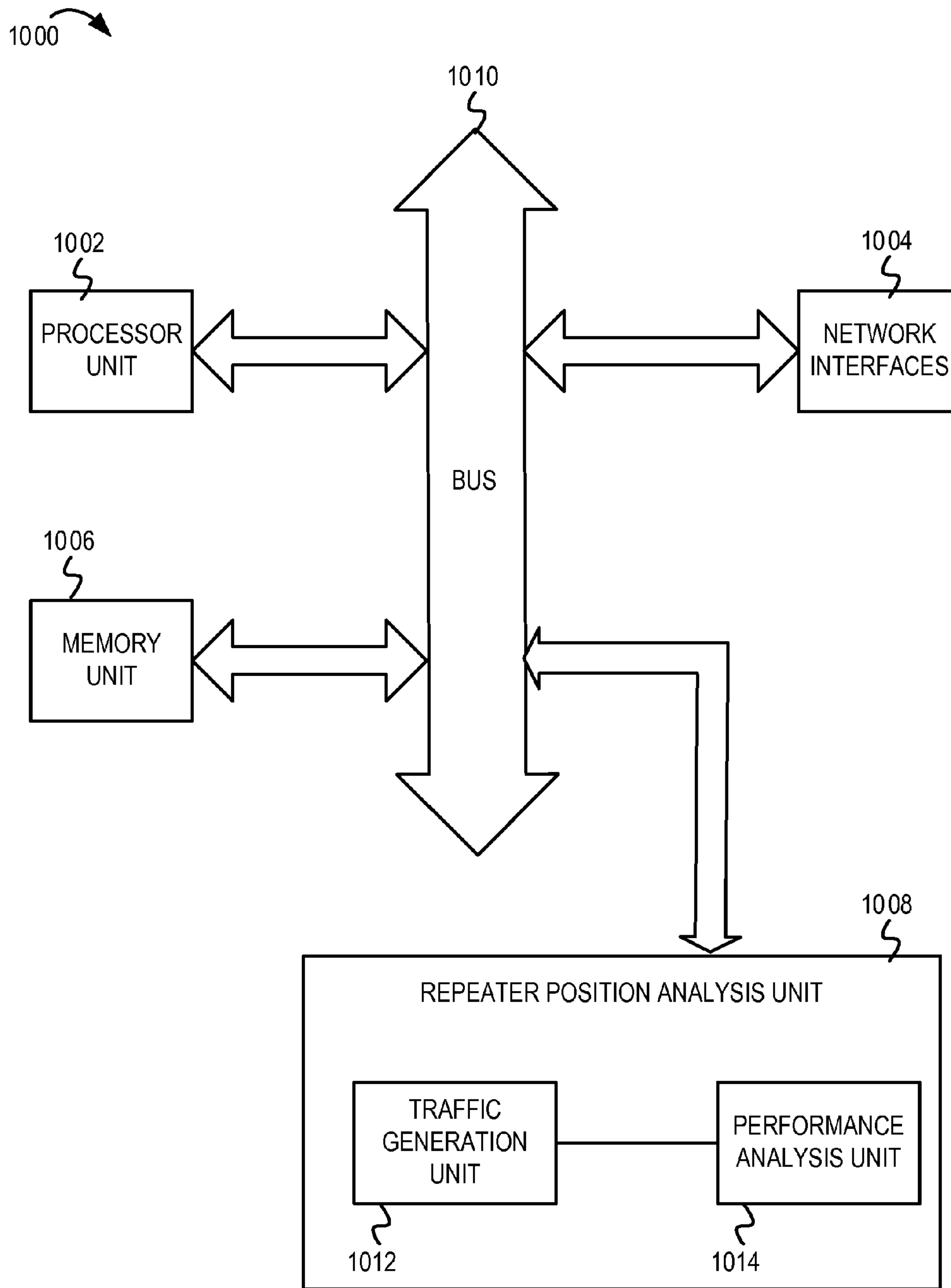


FIG. 10



## 1

**PLACEMENT OF WIRELESS REPEATERS IN  
A WIRELESS COMMUNICATION NETWORK**

## BACKGROUND

Embodiments of the inventive subject matter generally relate to the field of wireless communication networks and, more particularly, to a mechanism for placement of wireless repeaters in a wireless communication network.

Wireless repeaters are typically deployed for extending the communication range of an access point (or a gateway) in a wireless communication network. The position of the wireless repeater within the wireless communication network (e.g., horizontal position of the wireless repeater, height at which a wireless repeater is placed, an orientation of the wireless repeater relative to client stations in the wireless communication network, antenna orientation, etc.) can impact whether a communication link between the access point and the client stations can be established via the wireless repeater, whether performance requirements can be met, and how much communication bandwidth is available at the client stations.

## SUMMARY

Various embodiments of a mechanism for placement of wireless repeaters in a wireless communication network are disclosed. In one embodiment, a throughput associated with a communication link between a wireless repeater and an access point associated with a wireless communication network is determined. For each of one or more client stations associated with the wireless communication network, a throughput associated with a communication link between the wireless repeater and the client station is determined. For each of the one or more client stations, a cumulative throughput of a communication link between the access point and the client station via the wireless repeater is determined based on the throughput associated with the communication link between the wireless repeater and the access point, and based on the throughput associated with the communication link between the wireless repeater and the client station. It is determined, for each of the one or more client stations, whether the cumulative throughput is greater than or equal to a predetermined throughput threshold. Success of a current position of the wireless repeater with respect to the client station is indicated, in response to determining that the cumulative throughput is greater than or equal to the predetermined throughput threshold. Failure of the current position of the wireless repeater with respect to the client station is indicated, in response to determining that the cumulative throughput is less than the predetermined throughput threshold.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present embodiments may be better understood, and numerous objects, features, and advantages made apparent to those skilled in the art by referencing the accompanying drawings.

FIG. 1 is an example conceptual diagram illustrating operations of a wireless repeater configured for analyzing the position of the wireless repeater in a wireless communication network;

FIG. 2 is an example conceptual diagram illustrating operations of an access point configured for analyzing the position of a wireless repeater in a wireless communication network;

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FIG. 3 is a flow diagram illustrating example operations of a wireless repeater configured to analyze the suitability of the position of the wireless repeater in a wireless communication network;

FIG. 4 is a continuation of FIG. 3 and also illustrates example operations of the wireless repeater configured to analyze the suitability of the position of the wireless repeater in the wireless communication network;

FIG. 5 is a flow diagram illustrating example operations of an access point configured to analyze the suitability of the position of a wireless repeater in a wireless communication network;

FIG. 6 is a continuation of FIG. 5 and also illustrates example operations of the access point configured to analyze the suitability of the position of a wireless repeater in a wireless communication network;

FIG. 7 is a flow diagram illustrating example operations of the wireless repeater that operates in conjunction with the access point for analyzing the suitability of the position of the wireless repeater in a wireless communication network;

FIG. 8 is a continuation of FIG. 7 and also illustrates example operations of the wireless repeater that operates in conjunction with the access point for analyzing the suitability of the position of the wireless repeater in a wireless communication network;

FIG. 9 is an example timing diagram illustrating a mechanism for analyzing the suitability of the position of a wireless repeater in a wireless communication network; and

FIG. 10 is a block diagram of one embodiment of an electronic device including a mechanism for analyzing the suitability of the position of a wireless repeater in a wireless communication network.

## DESCRIPTION OF EMBODIMENT(S)

The description that follows includes exemplary systems, methods, techniques, instruction sequences, and computer program products that embody techniques of the present inventive subject matter. However, it is understood that the described embodiments may be practiced without these specific details. For instance, although examples refer to analyzing the current position of a wireless repeater in a wireless local area network (WLAN), embodiments are not so limited. In other embodiments, the operations for analyzing the current position of a wireless repeater can be implemented using other wireless communication standards and devices (e.g., Worldwide Interoperability for Microwave Access (WiMAX)). In other instances, well-known instruction instances, protocols, structures, and techniques have not been shown in detail in order not to obfuscate the description.

Traditionally, mechanisms for determining the position of a wireless repeater in a wireless communication network have relied on the received signal strength indicator (RSSI) associated with signals received at the wireless repeater. However, traditional mechanisms for determining the position of the wireless repeater may be unable to accurately estimate the communication bandwidth available to a client station when the wireless repeater is at a particular position. Consequently, the traditional mechanisms may be unable to determine whether the available bandwidth can support certain communications (e.g., transfer of video packets) from the access point to the client station. Furthermore, in some implementations, the client station may attempt to associate with the wireless repeater even if the RSSI associated with a signal received from the wireless repeater only marginally exceeds the RSSI associated with a signal received from the access point, which may result in a sub-optimal association scenario.



In other words, the traditional mechanisms for determining the position of the wireless repeater cannot control whether the client station should associate with the access point or with the wireless repeater. Therefore, in these scenarios, the communication bandwidth available to (and consequently the performance of) the client station when the client station associates with the wireless repeater may be much lower than the communication bandwidth available to (and consequently the performance of) the client station when the client station directly associates with the access point.

A repeater position analysis unit can be implemented on the wireless repeater and/or on the access point to determine an optimal position of the wireless repeater by taking into consideration various performance requirements (e.g., bandwidth and throughput requirements) associated with the client stations. The repeater position analysis unit can analyze the current position of the wireless repeater based on the throughput achieved on communication links between the access point, the repeater, and/or the client stations. In one embodiment, the wireless repeater can measure the throughput associated with communication links between the wireless repeater and the access point, and between the wireless repeater and the client stations, without assistance from the access point. The wireless repeater can then determine the suitability of the current position of the wireless repeater. In another embodiment, the access point in conjunction with the wireless repeater can determine the suitability of the current position of the wireless repeater based on the throughput associated with communication links between the access point and the wireless repeater, between the access point and the client stations, and between the wireless repeater and the client stations. Such a mechanism for determining the suitability of the current position of the wireless repeater can enable bandwidth, throughput, and other performance measurements to be estimated more accurately and can improve the performance of the wireless communication network. Furthermore, the access point in conjunction with the wireless repeater can determine whether each of the client stations should associate with the access point or with the wireless repeater, which may result in detection and reduction of sub-optimal associations in the wireless communication network.

FIG. 1 is an example conceptual diagram illustrating operations of a wireless repeater configured for analyzing the position of the wireless repeater in a wireless communication network 100. The wireless communication network 100 comprises an access point 102, a wireless repeater 104, a client station 106, and a client station 108. The wireless repeater 104 comprises a repeater position analysis unit 112. The repeater position analysis unit 112 comprises a traffic generation unit 114 and a performance analysis unit 116. In one implementation, the access point 102, the wireless repeater 104, and the client stations 106 and 108 may be a wireless local area network (WLAN) access point, a WLAN repeater, and WLAN client stations, respectively. In one implementation, the wireless communication network 100 can be employed for applications (e.g., video over wireless (VoW) applications) that are expected to meet certain predetermined performance requirements (e.g., a target bandwidth). In FIG. 1 (and as will subsequently be described in FIGS. 3-4), the access point 102 may not comprise functionality for determining throughput and/or for analyzing the current position of the wireless repeater 104. The wireless repeater 104 can itself execute operations for estimating the throughput of the wireless communication link between the access point 102 and the client stations 106 and 108 via the wireless repeater 104, as will be described below with reference to stages A-D.

At stage A, the traffic generation unit 114 generates and transmits training packets to the access point 102 and to each client station 106 and 108 in the wireless communication network 100. In one implementation, the training packets can comprise a predetermined data sequence encapsulated by suitable WLAN packet headers. It is noted, however, that in other implementation the training packets may be formed differently; for example, the training packets can comprise randomly generated data encapsulated by the WLAN packet headers. In some implementations, the traffic generation unit 114 may transmit one training packet to the access point 102, the client station 106, and the client station 108. In another implementation, the traffic generation unit 114 may transmit (across a predetermined number of time intervals) any suitable number of packets to the access point 102, the client station 106, and the client station 108. In response to the training packets, the traffic generation unit 114 can receive one or more acknowledgement messages from the access point 102, the client station 106, and the client station 108.

At stage B, the performance analysis unit 116 calculates the throughput associated with the wireless communication link between the wireless repeater 104 and each client station 106 and 108 (“repeater-client throughput”) and the throughput associated with the wireless communication link between the wireless repeater 104 and the access point 102 (“repeater-AP throughput”) based on the acknowledgement messages received at stage A. As will be described with reference to blocks 314-316 of FIGS. 3-4, the performance analysis unit 116 can determine one or more performance measurements (e.g., packet error rate or PER) associated with the acknowledgement messages received from the access point 102, the client station 106, and the client station 108. Based on these performance measurements, the performance analysis unit 116 can then calculate the repeater-AP throughput and the repeater-client throughputs.

At stage C, the performance analysis unit 116 estimates the throughput associated with the wireless communication link between the access point 102 and each client station 106 and 108 via the wireless repeater 104 (“AP-repeater-client throughput”). As will be described with reference to block 318 of FIG. 4, the performance analysis unit 116 can estimate the AP-repeater-client throughput for each of the client stations 106 and 108 based on the repeater-AP throughput and the repeater-client throughputs determined at stage B. The AP-repeater-client throughput for a particular client station is based on the repeater-AP throughput and the repeater-client throughput for the particular client station and may be referred to as a cumulative throughput.

At stage D, the performance analysis unit 116 identifies client stations for which the AP-repeater-client throughput exceeds a predetermined throughput threshold. As will be described below with reference to blocks 320-324 of FIG. 4, the performance analysis unit 116 can compare the AP-repeater-client throughput against a predetermined throughput threshold that is dependent, at least in part, on performance requirements associated with the client stations 106 and 108. The performance analysis unit 116 can identify client stations where the current position of the wireless repeater 104 satisfies the performance requirements associated with the client stations. For example, the performance analysis unit 116 may determine that the AP-repeater-client throughput associated with the client station 108 falls below the predetermined throughput threshold. Therefore, the performance analysis unit 116 can determine that the current position of the wireless repeater 104 does not satisfy the performance requirements associated with the client station 108. In some implementations, the wireless repeater 104 may be moved to a new



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position and the throughputs at the new position of the wireless repeater **104** may be analyzed to determine whether the new position of the wireless repeater **104** satisfies the performance requirements associated with the client stations **106** and **108**.

FIG. 2 is an example conceptual diagram illustrating operations of an access point configured for analyzing the position of a wireless repeater in a wireless communication network **200**. The wireless communication network **200** comprises an access point **202**, a wireless repeater **210**, a client station **206**, and a client station **208**. The wireless repeater **210** comprises a repeater position analysis unit **212**. The access point **202** also comprises a repeater position analysis unit **204**. In one implementation, the repeater position analysis units **204** and **212** can each include a traffic generation unit and a performance analysis unit (similar to the repeater position analysis unit **112** of FIG. 1). In one implementation, the access point **202**, the wireless repeater **210**, and the client stations **206** and **208** may be a wireless local area network (WLAN) access point, a WLAN repeater, and WLAN client stations, respectively. In FIG. 2 (and as will subsequently be described in FIGS. 5-9), the access point **202** may comprise functionality for determining throughput and/or for analyzing the current position of the wireless repeater **104**. The access point **202** in conjunction with the wireless repeater **210** can execute operations for analyzing the current position of the wireless repeater **210** and for determining whether the client stations **206** and **208** should connect to the access point **202** via a direct connection or via the wireless repeater **210**, as will be described below with reference to stages A-F.

At stage A, the repeater position analysis unit **204** calculates an access point throughput table comprising the throughput associated with wireless communication links between the access point **202** and the wireless repeater **210** (“AP-repeater throughput”), and between the access point **202** and each client station **206** and **208** (“AP-client throughput”) in the wireless communication network **200**. As will be described with reference to blocks 502-510 of FIG. 5, the repeater position analysis unit **204** transmits training packets to the client stations **206** and **208** and to the wireless repeater **210**, receives acknowledgement messages from the client stations **206** and **208** and the wireless repeater **210** in response to the training packets, determines performance measurements associated with the received acknowledgment messages, and determines the AP-repeater throughput and the AP-client throughputs based on the performance measurements. The repeater position analysis unit **204** can then store the AP-repeater throughput and the AP-client throughputs in the access point throughput table. After the access point throughput table is generated, the access point **202** can switch to a client mode and can cause the wireless repeater **210** to assume the role of the access point (i.e., switch to the access point mode) for measurement purposes in the wireless communication network **200**.

At stage B, the repeater position analysis unit **212** of the wireless repeater **210** calculates a repeater throughput table comprising the repeater-client throughput associated with each of the client stations **206** and **208**. As will be described with reference to blocks 312-316 of FIGS. 3-4 and with reference to blocks 708-714 of FIGS. 7-8, the repeater position analysis unit **212** transmits training packets to the client stations **206** and **208**, receives acknowledgement messages from the client stations **206** and **208** in response to the training packets, determines performance measurements associated with the received acknowledgment messages, and determines the repeater-client throughput based on the performance mea-

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surements. The repeater position analysis unit **212** can then store the repeater-client throughputs in the repeater throughput table.

At stage C, the repeater position analysis unit **212** provides the repeater throughput table to the access point **202**. Subsequently, the wireless repeater **210** can switch from the access point mode to the client mode, and the access point **202** can switch from the client mode to the access point mode.

At stage D, the repeater position analysis unit **204** determines an access point association table and a repeater association table based on the access point throughput table and the repeater throughput table. As will be described below with reference to blocks 516-526 of FIG. 6, the repeater position analysis unit **204** can calculate the AP-repeater-client throughput for each of the client stations **206** and **208** based on the access point throughput table and the repeater throughput table. For each of the client stations **206** and **208**, the repeater position analysis unit **204** can determine whether a direct wireless communication link between the access point **202** and the client station yields better performance as compared to a 1-hop wireless communication link between the access point **202** and the client station via the wireless repeater **210**. The access point association table can comprise a list of client stations where the AP-client throughput is better than the AP-repeater-client throughput. The repeater association table can comprise a list of client stations where the AP-repeater-client throughput is better than the AP-client throughput (e.g., by at least a predetermined percentage). The repeater position analysis unit **204** can also provide the repeater association table to the wireless repeater **210**.

At stage E, the wireless repeater **210** switches from the client mode to a repeater mode and permits client stations identified in the repeater association table to associate with the wireless repeater **210**. On receiving a control message (e.g., from the client station **206**) to connect to the wireless repeater **210**, the wireless repeater **210** can determine whether the client station **206** is listed in the repeater association table. If so, then on receiving an association request message from the client station **206**, the wireless repeater **210** can transmit an association response message and can associate with the client station **206**. If the client station **206** is not listed in the repeater association table, then on receiving an association request message from the client station **206**, the wireless repeater **210** can transmit an association failed response. In other words, the wireless repeater **210** can prevent association with (or block) the client station **206** and therefore, effectively cause the client station **206** to associate with the access point **202**.

At stage F, the access point **202** connects to and associates with client stations identified in the access point association table. On receiving a control message (e.g., from the client station **208**) to connect to the access point **202**, the access point **202** can determine whether the client station **208** is listed in the access point association table. If so, then on receiving an association request message from the client station **208**, the access point **202** can transmit an association response message and can associate with the client station **208**. If the client station **208** is not listed in the access point association table, then on receiving an association request message from the client station **208**, the access point **202** can block the client station **208** and therefore, effectively cause the client station **208** to associate with the wireless repeater **210**.

FIG. 3 and FIG. 4 depict a flow diagram (“flow”) **300** illustrating example operations of a wireless repeater config-



ured to analyze the suitability of the position of the wireless repeater in a wireless communication network. The flow 300 begins at block 302 in FIG. 3.

At block 302, a wireless repeater determines to analyze throughput at the current position of the wireless repeater in a wireless communication network. For example, with reference to FIG. 1, the repeater position analysis unit 112 of the wireless repeater 104 can determine to analyze the suitability of the current position of the wireless repeater 104 in the wireless communication network 100. In some implementations, the repeater position analysis unit 112 can analyze the suitability of the current position of the wireless repeater 104 in response to a trigger from a network administrator. In another implementation, the repeater position analysis unit 112 can analyze the suitability of the current position of the wireless repeater 104 at periodic intervals. In another implementation, the repeater position analysis unit 112 can analyze the suitability of the current position of the wireless repeater 104 in response to detecting (or receiving an indication of) performance degradation in the wireless communication network 100. In one implementation, the repeater position analysis unit 112 can be enabled in response to determining to analyze the suitability of the current position of the wireless repeater 104. The flow continues at block 304.

At block 304, one or more client stations in the wireless communication network are identified. For example, the repeater position analysis unit 112 can identify the client stations 106 and 108 in the wireless communication network 100. The repeater position analysis unit 112 can also identify the access point 102 associated with the wireless communication network 100. In one implementation, the network administrator may program information identifying the client stations 106 and 108 and the access point 102 in the repeater position analysis unit 112. In another implementation, the repeater position analysis unit 112 can automatically identify the client stations 106 and 108 and the access point 102. The flow continues at block 306.

At block 306, the repeater-AP throughput associated with a wireless communication link between the access point of the wireless communication network and the wireless repeater is calculated. For example, the repeater position analysis unit 112 can calculate the repeater-AP throughput. As will be described below with reference to blocks 310-316, to calculate the repeater-AP throughput, the traffic generation unit 114 can transmit one or more training packets to the access point 102 and receive acknowledgment messages (in response to the one or more training packets) from the access point 102. Based on performance measurements determined from the acknowledgment messages, the performance analysis unit 116 can calculate the repeater-AP throughput in accordance with Eq. 1 (described with reference to block 316). The flow continues at block 308.

At block 308, a loop begins for each of the one or more client stations in the wireless communication network. For example, the repeater position analysis unit 112 can initiate a loop to analyze each of the client stations 106 and 108 in the wireless communication network 100. As will be described below with reference to blocks 310-326, the repeater position analysis unit 112 can identify client stations at which the current position of the wireless repeater 104 satisfies performance requirements associated with the client stations. The flow continues at block 310.

At block 310, a training packet is transmitted to the client station. For example, the traffic generation unit 114 can transmit the training packet to the client station 106. In one implementation, the training packet can comprise predetermined data (e.g., a predetermined combination of zeros and ones). In

another implementation, the traffic generation unit 114 can randomly generate (e.g., using a random number generator) the data to be transmitted within the training packet. The flow continues at block 312.

At block 312, an acknowledgment message is received from the client station in response to the training packet. For example, the traffic generation unit 114 can receive an acknowledgment message (e.g., an ACK packet, a block ACK packet, etc.) that indicates successful reception of the training packet at the client station 106. The flow continues at block 314.

At block 314, one or more performance measurements are determined based on the received acknowledgment message. For example, the performance analysis unit 116 can determine one or more performance measurements in response to receiving the acknowledgment message from the client station 106 (at block 312). In one implementation, the performance analysis unit 116 can determine a data communication rate (e.g., a physical layer (PHY) rate), a packet error rate (PER), a packet success rate, a number of overhead bits exchanged via the wireless communication link (i.e., a total number of overhead bits in the training packet and the acknowledgment message), and/or other performance measurements. The number of overhead bits can vary depending on the communication protocol implemented by the wireless repeater 104 and the client station 106. In one implementation, the performance analysis unit 116 may not determine the exact number of overhead bits exchanged via the wireless communication link between the wireless repeater 104 and the client station 106. Instead, the performance analysis unit 116 may estimate (or heuristically determine) a factor (k) that is proportional to the number of overhead bits exchanged via the wireless communication link between the wireless repeater 104 and the client station 106. The flow continues at block 316 in FIG. 4.

At block 316, the repeater-client throughput associated with the wireless communication link between the wireless repeater and the client station is calculated based on the one or more performance measurements. For example, the performance analysis unit 116 can determine the repeater-client throughput associated with the client station 106 based on the one or more performance measurements determined at block 314. In one implementation, the repeater-client throughput can be calculated as a product of the PHY rate, the packet success rate, and the number of overhead bits exchanged via the wireless communication link, as depicted with reference to Eq. 1. With reference to Eq. 1, k represents a scale factor that is proportional to the overhead associated with the communication protocol implemented at the wireless repeater 104 and at the client station 106. Also, the factor  $k \cdot \text{PHY rate}$  represents the effective throughput achieved for a specified PHY rate.

$$\text{Throughput} = k \cdot \text{PHY rate} \cdot (1 - \text{PER})$$

Eq. 1

It is noted that Eq. 1 is one example representation of the repeater-client throughput. It is noted that the repeater-AP throughput and the repeater-client throughput calculated based on the product of the PHY rate, the packet success rate, and the number of overhead bits exchanged via the wireless communication link (as depicted with reference to Eq. 1) may also be referred to as the repeater-AP goodput and the repeater-client goodput, respectively. In one example, goodput can be defined as a measure of useful bits exchanged via the wireless communication links, and which excludes dropped packets, packet retransmissions, and protocol overhead. In other implementations, the repeater-client throughput (and the repeater-AP throughput) can be calculated using



any suitable combination of performance measurements and/or any suitable throughput (or goodput) estimation techniques. For example, in addition to the PHY rate, the PER, and the number of overhead bits, other performance measurements such as RSSI, error vector magnitude (EVM), etc. can also be taken into consideration in calculating the repeater-client throughput. In other embodiments, instead of calculating the repeater-client throughput, individual performance measurements (e.g., the PER) can be analyzed to quantify the position of the wireless repeater **104**. In some implementations, the performance analysis unit **116** can also populate a repeater throughput table. The repeater throughput table can comprise identifying information (e.g., a network address and/or association ID) associated with the client station **106** and the corresponding repeater-client throughput. The performance analysis unit **116** can maintain the repeater throughput table in a file, a predetermined memory location, an external storage device, or other suitable storage locations. The flow continues at block **318**.

At block **318**, the AP-repeater-client throughput (referred to as cumulative throughput) is estimated based on the repeater-AP throughput and the repeater-client throughput. The AP-repeater-client throughput can be representative of the throughput associated with the wireless communication link between the access point **102** and the client station **102** via the wireless repeater **104**. For example, the performance analysis unit **116** can estimate the AP-repeater-client throughput based on the repeater-AP throughput (determined at block **306**) and the repeater-client throughput (determined at block **316**). In some implementations, the performance analysis unit **116** can calculate the AP-repeater-client throughput in accordance with Eq. 2. In other implementations, the performance analysis unit **116** can calculate the AP-repeater-client throughput in accordance with Eq. 3, which is a simplified representation of Eq. 2. The flow continues at block **320**.

$$\text{AP\_repeater\_client throughput} = \frac{(\text{repeater\_AP throughput}) * (\text{repeater\_client throughput})}{(\text{repeater\_AP throughput}) + (\text{repeater\_client throughput})} \quad \text{Eq. 2}$$

$$\text{AP\_repeater\_client throughput} = \frac{1}{2} * \min(\text{repeater\_AP throughput}, \text{repeater\_client throughput}) \quad \text{Eq. 3}$$

The AP-repeater-client throughput (i.e., cumulative throughput) may be estimated by a variety of ways. For example, shown in Eq. 2, the AP-repeater-client throughput may be determined by calculating a product of the throughput associated with the communication link between the wireless repeater and the access point and the throughput associated with the communication link between the wireless repeater and the client station; calculating a sum of the throughput associated with the communication link between the wireless repeater and the access point and the throughput associated with the communication link between the wireless repeater and the client station; and dividing the calculated product by the calculated sum to yield the cumulative throughput of the communication link between the access point and the client station via the wireless repeater. In the example, shown in Eq. 3, the AP-repeater client throughput may be determined by determining a minimum throughput value between the throughput associated with the communication link between the wireless repeater and the access point and the throughput associated with the communication link between the wireless

repeater and the client station; and multiplying the determined minimum throughput value by a predetermined scale factor to yield the cumulative throughput of the communication link between the access point and the client station via the wireless repeater.

At block **320**, it is determined whether the estimated AP-repeater-client throughput is greater than a predetermined throughput threshold. For example, the performance analysis unit **116** can determine whether the AP-repeater-client throughput (determined at block **318**) is greater than the predetermined throughput threshold. In one implementation, the performance analysis unit **116** can calculate the predetermined throughput threshold based on throughput requirements associated with the wireless repeater **104**, the access point **102**, the client stations **106** and **108**, and/or the wireless communication network **100**. In some implementations, the predetermined throughput threshold is also configurable. If it is determined that the estimated AP-repeater-client throughput is greater than the predetermined throughput threshold, the flow continues at block **322**. Otherwise, the flow continues at block **324**.

At block **322**, it is determined that the current position of the wireless repeater satisfies performance requirements for the client station. The flow **300** moves from block **320** to block **322** if the performance analysis unit **116** determines that the estimated AP-repeater-client throughput is greater than the predetermined throughput threshold. The AP-repeater-client throughput being greater than the predetermined throughput threshold can indicate that the wireless repeater **104** can satisfy the throughput requirements associated with the client station **106** when the wireless repeater **104** is at its current position. The performance analysis unit **116** can indicate success of the current position of the wireless repeater **104** with respect to the client station **106** using LEDs or a display unit. For example, the performance analysis unit **116** can switch on the LED associated with the client station **106** in response to determining that the wireless repeater **104** satisfies the performance requirements associated with the client station **106**. As another example, the performance analysis unit **116** can present the address of the client station **106** and the AP-repeater-client throughput on the display unit (e.g., LCD display), and can indicate success of the current position of the wireless repeater **104** with respect to the client station **106** on the display unit. The flow continues at block **326**.

At block **324**, it is determined that the current position of the wireless repeater does not satisfy performance requirements for the client station. The flow **300** moves from block **320** to block **324** if the performance analysis unit **116** determines that the estimated AP-repeater-client throughput is less than the predetermined throughput threshold. The AP-repeater-client throughput being less than the predetermined throughput threshold can indicate that the wireless repeater **104** cannot satisfy the throughput requirements associated with the client station **108** when the wireless repeater **104** is at its current position. The performance analysis unit **116** can indicate failure of the current position of the wireless repeater **104** with respect to the client station **108** using LEDs or the display unit (similarly as was described above). For example, the performance analysis unit **116** may not switch on the LED associated with the client station **108**, or may present a failure notification on the display unit (e.g., LCD display), in response to determining that the wireless repeater **104** does not satisfy the performance requirements associated with the client station **108**. The flow continues at block **326**.

At block **326**, it is determined whether additional client stations in the wireless communication network are to be



analyzed. For example, the performance analysis unit **116** can determine whether additional client stations are to be analyzed. If it is determined that there exist additional client stations in the wireless communication network **100** to be analyzed, the flow continues at block **308** in FIG. **3**, where the next client station is identified and operations described above with reference to blocks **310-326** are executed for the next client station. Otherwise, the flow ends.

It is noted that although FIG. **3** depicts the traffic generation unit **114** transmitting one training packet to the access point **102** and to each of the client stations **106** and **108**, embodiments are not so limited. In some implementations, the traffic generation unit **114** may transmit any suitable number of training packets during different time intervals and may receive one or more acknowledgement messages in response to the training packets. The performance analysis unit **116** may then determine the performance measurements based on the received one or more acknowledgement messages. Furthermore, although FIG. **3** depicts the traffic generation unit **114** successively transmitting the training packets to the access point **102** and to each of the client stations **106** and **108**, embodiments are not so limited. In other embodiments, the traffic generation unit **114** may broadcast the training packets to all the wireless devices (e.g., the access point **102**, the client station **106**, and the client station **108**) in the wireless communication network **100** simultaneously. The traffic generation unit **114** can then wait to receive (from each of the wireless devices) acknowledgement messages that indicate successful receipt of the broadcast training packet.

In some implementations, as will be further described with reference to FIGS. **5-8**, both the access point and the wireless repeater can be configured to implement functionality for analyzing the suitability of the current position of the wireless repeater. Such a mechanism can improve the accuracy associated with the analysis of the current position of the wireless repeater and can minimize sub-optimal associations. FIGS. **5-6** further describe operations of the access point implementing functionality for analyzing the throughputs at the current position of the wireless repeater. FIGS. **7-8** describe operations of the wireless repeater implementing functionality (when assisted by the access point) for analyzing the throughputs at the current position of the wireless repeater.

FIG. **5** and FIG. **6** depict a flow diagram **500** illustrating example operations of an access point configured to analyze the suitability of the position of a wireless repeater in a wireless communication network. The flow **500** begins at block **502** in FIG. **5**.

At block **502**, an access point determines to analyze the throughput at the current position of a wireless repeater in a wireless communication network. For example, with reference to FIG. **2**, repeater position analysis unit **204** of the access point **202** can determine to analyze the throughput at, and the suitability of, the current position of the wireless repeater **210** in the wireless communication network **200**. The repeater position analysis unit **202** can determine to analyze the suitability of the current position of the wireless repeater **210** in response to a trigger from a network administrator, at periodic intervals, in response to detecting performance degradation in the wireless communication network **200**, and/or based on other criteria. The flow continues at block **504**.

At block **504**, one or more client stations associated with the access point in the wireless communication network are identified. For example, the repeater position analysis unit **204** can identify the client stations **206** and **208** in the wireless communication network **200**. Because the client stations **206** and **208** exchange control messages for connecting to and associating with the access point **202**, the access point **202**

can keep track of the client stations **206** and **208** with which it has established a wireless communication link. In some examples, the repeater position analysis unit **204** can access a predetermined memory location associated with the access point **202** where the client station information is stored, or can query an access point connection manager to determine the client stations **206** and **208** associated with the access point **202**. The flow continues at block **506**.

At block **506**, for each of the one or more client stations, the AP-client throughput associated with a wireless communication link between the access point and the client station is calculated. For example, the repeater position analysis unit **204** of the access point **202** can calculate the AP-client throughput for each of the client stations **206** and **208** associated with the access point **202**. As described above with reference to blocks **310-316** of FIGS. **3-4**, the repeater position analysis unit **204** can transmit one or more training packets to the client stations **206** and **208**. The repeater position analysis unit **204** can receive acknowledgement messages from the client stations **206** and **208** indicating successful reception of the training packets. The repeater position analysis unit **204** can determine performance measurements associated with the received acknowledgement messages and can calculate the AP-client throughput based on the performance measurements (e.g., using Eq. 1 shown above). In some implementations, if the repeater position analysis unit **204** determines multiple values of the AP-client throughput across multiple time intervals, the repeater position analysis unit **204** can calculate an average AP-client throughput. The flow continues at block **508**.

At block **508**, the AP-repeater throughput associated with a wireless communication link between the access point and the wireless repeater is calculated. For example, the repeater position analysis unit **204** can calculate the AP-repeater throughput associated with the wireless communication link between the access point **202** and the wireless repeater **210**. As described above with reference to blocks **310-316** of FIGS. **3-4**, the repeater position analysis unit **204** can transmit one or more training packets to the wireless repeater **210**. The repeater position analysis unit **204** can receive acknowledgement messages from the wireless repeater **210** indicating successful receipt of the training packets. The repeater position analysis unit **204** can determine performance measurements associated with the received acknowledgement messages and can calculate the AP-repeater throughput (or an average AP-repeater throughput) based on the performance measurements (e.g., using Eq. 1 shown above). The flow continues at block **510**.

At block **510**, an access point throughput table comprising the AP-repeater throughput and the AP-client throughput associated with each of the one or more client stations is populated. For example, the repeater position analysis unit **204** can store the AP-repeater throughput (or the average AP-repeater throughput) and the AP-client throughput (or the AP-client throughput) associated with each of the client stations **206** and **208** in the access point throughput table. The flow continues at block **512**.

At block **512**, the access point switches to a client mode and causes the wireless repeater to determine the repeater-client throughput associated with each of the one or more client stations. For example, after the access point throughput table is generated, the repeater position analysis unit **204** can provide a control message to the wireless repeater **210** to cause the wireless repeater **210** to switch from a client mode to an access point mode. The repeater position analysis unit **204** can then cause the access point **202** to switch to the client mode. After the access point **202** switches to the client mode,



the client stations **206** and **208** previously associated with the access point **202** can disassociate from the access point **202**. The client stations **206** and **208** can then associate with the wireless repeater **210** that is configured in the access point mode. As will further be described with reference to FIGS. **7-8**, after switching to the access point mode, the wireless repeater **210** can determine the repeater-client throughput associated with each of the client stations **206** and **208** in the wireless communication network **200**. The flow continues at block **514**.

At block **514**, a repeater throughput table comprising the repeater-client throughput associated with each of the one or more client stations is received. For example, the repeater position analysis unit **204** can receive, from the wireless repeater **210**, the repeater throughput table comprising the repeater-client throughput associated with each of the client stations **206** and **208**. Operations of the wireless repeater **210** determining the repeater-client throughput and determining the repeater throughput table will be further described below in FIGS. **7-8**. The flow continues at block **515**.

At block **515**, the access point switches from the client mode to the access point mode. For example, on receiving the repeater throughput table, the repeater position analysis unit **204** can cause the access point **202** to switch to the access point mode. Furthermore, on receiving the repeater throughput table, the access point **202** can transmit another control message to the wireless repeater **210** to cause the wireless repeater **210** to switch back to the client mode. After the access point **202** switches to the access point mode, the client stations **206** and **208** previously associated with the wireless repeater **210** can disassociate from the wireless repeater **210**. The client stations **206** and **208** can then associate with the access point **202** that is configured in the access point mode. The flow continues at block **516** in FIG. **6**.

At block **516**, a loop begins for each of the one or more client stations in the wireless communication network. For example, the repeater position analysis unit **204** can initiate a loop to analyze each of the client stations **206** and **208** in the wireless communication network **200**. As will be further described below with reference to blocks **518-526**, based on the repeater throughput table and the access point throughput table, the repeater position analysis unit **204** can determine whether a direct connection with each client station or a 1-hop connection with each client station via the wireless repeater **210** yields the best throughput. The flow continues at block **518**.

At block **518**, an AP-repeater-client throughput (cumulative throughput) is calculated based on the AP-repeater throughput and the repeater-client throughput. For example, the repeater position analysis unit **204** can calculate the AP-repeater-client throughput based on the AP-repeater throughput (determined at block **508**) and the repeater-client throughput (received in the repeater throughput table at block **514**). The AP-repeater-client throughput for the client station **206** can be representative of the throughput achieved on the wireless communication link between the access point **202** and the client station **206** via the wireless repeater **210**. In some implementations, the repeater position analysis unit **204** can calculate the AP-repeater-client throughput in accordance with Eq. 4. In other implementations, the repeater position analysis unit **204** can calculate the AP-repeater-client throughput in accordance with Eq. 5, which is a simplified variant of Eq. 4. The flow continues at block **520**.

$$\text{AP\_repeater\_client throughput} = \frac{(\text{AP\_repeater throughput}) * (\text{repeater\_client throughput})}{(\text{AP\_repeater throughput}) + (\text{repeater\_client throughput})} \quad \text{Eq. 4}$$

$$\text{AP\_repeater\_client throughput} = \frac{1}{2} * \min(\text{AP\_repeater throughput}, \text{repeater\_client throughput}) \quad \text{Eq. 5}$$

At block **520**, it is determined whether the AP-client throughput is greater than the AP-repeater-client throughput. For example, the repeater position analysis unit **204** can determine whether the AP-client throughput is greater than the AP-repeater-client throughput. In other words, the repeater position analysis unit **204** can determine whether directly communicating with the client station **206** will yield a better performance than communicating with the client station **206** via the wireless repeater **210**. In some implementations, the repeater position analysis unit **204** may simply determine whether the AP-client throughput is greater than the AP-repeater-client throughput to determine whether the client station **206** should connect to the access point **202** via a direct connection or via the wireless repeater **210**. In another implementation, the repeater position analysis unit **204** may determine whether the AP-repeater-client throughput is greater than the AP-client throughput by a predetermined margin (e.g., by 25%) to determine whether the client station **206** should connect to the access point **202** via a direct connection or via the wireless repeater **210**. The predetermined margin can be configurable and can be selected to maintain a balance between decrease in communication bandwidth if the client station **206** connects to the access point **202** via the wireless repeater **210** and a corresponding increase in throughput. In one example, the predetermined margin can be selected to be 25%. In another example, the predetermined margin can be selected to be 15%. In determining whether the client station **206** should connect to the access point **202** via a direct connection or via the wireless repeater **210**, the repeater position analysis unit **204** may also take available communication bandwidth and the performance requirements associated with the client station **206**, the access point **202**, and the wireless repeater **210** into consideration. If it is determined that the AP-client throughput is greater than the AP-repeater-client throughput, the flow continues at block **522**. Otherwise, the flow continues at block **524**.

At block **522**, it is indicated in an access point association table that the client station should associate directly with the access point. The flow **500** moves from block **520** to block **522** if the repeater position analysis unit **204** determines that the AP-client throughput associated with the client station is greater than the AP-repeater-client throughput associated with the same client station. The access point association table can comprise a list of client stations with which the access point **202** can associate (e.g., on receiving an association request message from the client stations). The access point **202** can block all other client stations (not listed within the access point association table) that have a higher AP-repeater-client throughput as compared to the AP-client throughput. For example, the repeater position analysis unit **204** can indicate, in the access point association table, that the client station **206** should associate directly with the access point **202**. Thus, the access point **202** can associate with the client station **206** in response to receiving an association request message from the client station **206**. However, in response to receiving an association request message from the client station **208**, the access point **202** can transmit an asso-



ciation denied message and can prevent association with the client station 208. The flow continues at block 526.

At block 524, it is indicated in a repeater association table that the client station should connect to the access point via the wireless repeater. The flow 500 moves from block 520 to block 524 if the repeater position analysis unit 204 determines that the AP-client throughput is not greater than the AP-repeater-client throughput. The repeater association table can comprise a list of client stations with which the wireless repeater 210 can associate (e.g., on receiving an association request message from the client stations). For example, the repeater position analysis unit 204 can indicate, in the repeater association table, that the wireless repeater 210 should associate with the client station 208. The flow continues at block 526.

At block 526, it is determined whether additional client stations in the wireless communication network are to be analyzed. For example, the repeater position analysis unit 204 can determine whether additional client stations are to be analyzed. If it is determined that additional client stations in the wireless communication network 200 are to be analyzed, the flow continues at block 516 where a next client station is identified and operations described above with reference to blocks 518-526 are executed for the next client station. Otherwise, the flow continues at block 528.

At block 528, an indication of the repeater association table is provided to the wireless repeater. For example, the repeater position analysis unit 204 can provide the repeater association table to the wireless repeater 210. As will be described with reference to FIG. 8, the wireless repeater 210 can associate with the client stations that are included in the repeater association table. The flow continues at block 530.

At block 530, client stations identified in the access point association table are permitted to associate with the access point. For example, as described above, the access point can permit client stations identified in the access point association table to associate with the access point (e.g., the access point can transmit association response messages) and can block client stations that are not identified in the access point association table. From block 530, the flow ends.

It is noted that in some implementations, the repeater position analysis unit 204 can determine whether the AP-repeater-client throughput and the AP-client throughput are greater than the predetermined throughput threshold, as described with reference to block 320 of FIG. 4. If only one of the AP-repeater-client throughput or the AP-client throughput is greater than the predetermined throughput threshold, the repeater position analysis unit 204 can select the wireless communication link that yields the throughput that is greater than the predetermined throughput threshold. For example, if the repeater position analysis unit 204 determines that the AP-repeater-client throughput is greater than the predetermined throughput threshold and that the AP-client throughput is less than the predetermined throughput threshold, the repeater position analysis unit 204 can indicate that the client station 206 should connect to the access point 202 via the wireless repeater 210. However, if both the AP-repeater-client throughput and the AP-client throughput are greater than the predetermined throughput threshold, the repeater position analysis unit 204 can execute operations described with reference to block 520-524 of FIG. 6. Furthermore, in some implementations if the AP-repeater-client throughput and the AP-client throughput are both less than the predetermined throughput threshold, the repeater position analysis unit 204 can indicate that performance requirements associated with the client station 206 cannot be satisfied. Then, the repeater position analysis unit 204 can prompt the network adminis-

trator to move the wireless repeater 210 to another position for subsequent analysis of the suitability of the new position of the wireless repeater 210.

FIG. 7 and FIG. 8 depict a flow diagram 700 illustrating example operations of the wireless repeater that operates in conjunction with the access point for analyzing the suitability of the current position of the wireless repeater in a wireless communication network. The flow 700 begins at block 702 in FIG. 7.

At block 702, the wireless repeater is initialized in the client mode and is associated with an access point of a wireless communication network. For example, with reference to FIG. 2, after the wireless repeater 210 is powered on, the wireless repeater 210 can initialize in the client mode. The wireless repeater 210 can detect and associate with the access point 202 of the wireless communication network 200. The flow continues at block 704.

At block 704, a training packet is received from the access point. For example, the repeater position analysis unit 212 of the wireless repeater 210 can receive the training packet from the access point 202. It is noted that, in some implementations, the repeater position analysis unit 212 can receive more than one training packet from the access point 202 during different time intervals. The flow continues at block 706.

At block 706, an acknowledgement message is transmitted to the access point in response to receiving the training packet. For example, the repeater position analysis unit 212 can transmit the acknowledgement message (e.g., an ACK packet) to the access point 202 to indicate successful receipt of the training packet at the wireless repeater 210. In one implementation, if the repeater position analysis unit 212 receives more than one training packet from the access point 202, the repeater position analysis unit 212 can transmit a separate acknowledgment message to indicate receipt of each training packet. In another implementation, if the repeater position analysis unit 212 receives more than one training packet from the access point 202, the repeater position analysis unit 212 can transmit one or more block acknowledgment messages (e.g., a block ACK packet) to indicate receipt of multiple training packets. The flow continues at block 708.

At block 708, an indication to calculate the repeater-client throughput is received from the access point. For example, the repeater position analysis unit 212 can receive a control message from the corresponding repeater position analysis unit 204 of the access point 202 instructing the wireless repeater 210 to change from a client mode to an access point mode. The access point 202 can also prompt the repeater position analysis unit 212 to calculate the repeater-client throughput associated with each of the client stations 206 and 208 in the wireless communication network 200. The flow continues at block 710.

At block 710, the wireless repeater switches to the access point mode and associates with the one or more client stations of the wireless communication network. For example, in response to receiving the indication to calculate the repeater-client throughput at block 708, the wireless repeater 210 can switch from the client mode to the access point mode. When configured in the access point mode, the wireless repeater 210 can associate with the client stations 206 and 208 of the wireless communication network 200. As described above, the wireless repeater 210 can also associate with the access point 202, after the access point 202 switches from the access point mode to the client mode. The flow continues at block 712.

At block 712, the repeater-client throughput is calculated for each of the one or more client stations associated with the wireless repeater. For example, the repeater position analysis



unit 212 can calculate the repeater-client throughput associated with the client stations 206 and 208. As described above with reference to blocks 310-316 of FIGS. 3 and 4, the repeater position analysis unit 212 can transmit one or more training packets to the client stations 206 and 208 and can receive acknowledgement messages from the client stations 206 and 208. The repeater position analysis unit 212 can determine performance measurements associated with the received acknowledgement messages. Consequently, the repeater position analysis unit 212 can calculate the repeater-client throughput associated with each of the client stations 206 and 208 based on the determined performance measurements (e.g., by using Eq. 1 shown above). The flow continues at block 714 in FIG. 8.

At block 714, a repeater throughput table is populated with the repeater-client throughput associated with each of the one or more client stations. For example, the repeater position analysis unit 212 can store the repeater-client throughput associated with the client stations 206 and 208 in the repeater throughput table. The flow continues at block 716.

At block 716, the repeater throughput table is provided to the access point. For example, the repeater position analysis unit 212 can transmit the repeater throughput table to the access point 202. As described above, with reference to FIGS. 5-6, the access point 202 can use the repeater throughput table in conjunction with the access point throughput table to analyze the suitability of the current position of the wireless repeater 210, and to determine whether the client stations 206 and 208 should directly connect to the access point 202 or should connect to the access point 202 via the wireless repeater 210. The flow continues at block 718.

At block 718, the wireless repeater switches from the access point mode to the client mode. In one implementation, the repeater position analysis unit 212 can receive a control message from the access point 202 instructing the wireless repeater 210 to switch from the access point mode to the client mode. Consequently, the repeater position analysis unit 212 can cause the wireless repeater 210 to switch to the client mode. In another implementation, the repeater position analysis unit 212 can cause the wireless repeater 210 to switch to the client mode as soon as the repeater throughput table is provided to the access point 202. In another implementation, the repeater position analysis unit 212 can wait to receive an acknowledgement message that indicates receipt of the repeater throughput table at the access point 202. The repeater position analysis unit 212 can retransmit the repeater throughput table if the acknowledgment message is not received. In some implementations, the repeater position analysis unit 212 can abort operations for analyzing the suitability of the current position of the wireless repeater 210 if the acknowledgement message is not received within a predetermined timeout interval and/or after a predetermined number of retransmission attempts. Consequently, the repeater position analysis unit 212 can cause the wireless repeater 210 to switch to the client mode. The flow continues at block 720.

At block 720, a repeater association table is received from the access point. For example, the repeater position analysis unit 212 can receive the repeater association table from the access point 202. The repeater association table can comprise a list of client stations with which the wireless repeater 210 can associate (e.g., in response to receiving an association request message from the client stations). As described above, the client stations identified in the repeater association table are associated with an AP-repeater-client throughput that is greater than the AP-client throughput. The flow continues at block 722.

At block 722, an acknowledgement message indicating receipt of the repeater association table is transmitted to the access point. For example, the repeater position analysis unit 212 can transmit (to the access point 202) the acknowledgement message indicating receipt of the repeater association table. The flow continues at block 724.

At block 724, the wireless repeater associates with client stations indicated in the repeater association table. The wireless repeater 210 can switch from the client mode to a repeater mode and can permit client stations identified in the repeater association table to associate with the wireless repeater 210. The wireless repeater 210 can block (and prevent association with) all other client stations (not listed on the repeater association table) that have a higher AP-client throughput as compared to the AP-repeater-client throughput. For example, the repeater association table may indicate that the client station 208 should connect to the access point 202 via the wireless repeater 210. Thus, the wireless repeater 210 can associate with the client station 208 in response to receiving an association request message from the client station 208. However, if an association request message is received from the client station 206, the wireless repeater 210 can transmit an association denied message, can prevent association with the client station 206, and/or can cause the client station 206 to directly connect to and associate with the access point 202. From block 724, the flow ends.

In some implementations, finite state machines can be implemented on the access point 202 and on the wireless repeater 210 to facilitate the exchange of throughput tables, association tables, and other control messages between the access point 202 and the wireless repeater 210. The timing diagram 900 of FIG. 9 illustrates example messages exchanged between the access point 202 and the wireless repeater 210 for analyzing the suitability of the current position of the wireless repeater 210.

FIG. 9 is an example timing diagram 900 illustrating a mechanism for analyzing the suitability of the position of the wireless repeater 210 in the wireless communication network 200. After the access point 202 and the wireless repeater 210 are powered on, the access point 202 initializes in the access point mode (depicted in state 902), while the wireless repeater 210 initializes in the client mode (depicted in state 904). The wireless repeater 210 and other client stations (not shown in the timing diagram 900) associate with the access point 202. As depicted by the state 902, the access point 202 calculates the access point throughput table (described above with reference to blocks 506-510 of FIG. 5). At state 906, the access point 202 identifies and selects the wireless repeater 210. The access point 202 transmits a control message 908 directing the wireless repeater 210 to switch from the client mode to the access point mode. The wireless repeater 210 transmits the acknowledgment message 910 in response to receiving the control message 908. It is noted that if the access point 202 does not receive the acknowledgment message 910, the access point 202 can retransmit the control message 908 until it receives the acknowledgment message 910 or until a predetermined timeout duration elapses. After the predetermined timeout duration elapses, the access point 202 can abort operations for analyzing the suitability of the current position of the wireless repeater 210 and can remain in the access point mode.

After the access point 202 receives the acknowledgment message 910, the access point 202 switches to the client mode as depicted in state 912. As depicted by state 914, the wireless repeater 210 switches to the access point mode. The access point 202 in the client mode (and the other client stations) associates with the wireless repeater 210 configured in the



access point mode. At state **914**, the wireless repeater **210** also determines the repeater throughput table as described above with reference to blocks **712-714** of FIG. **6-7**. The wireless repeater **210** transmits (to the access point **202**) a message **916** comprising the repeater throughput table. The access point **202** transmits another control message **918** directing the wireless repeater **210** to switch from the access point mode to the client mode. The wireless repeater **210** transmits the acknowledgment message **920** in response to receiving the control message **918**. As described above, in some implementation, the access point **202** can retransmit the control message **918** if the access point **202** does not receive the acknowledgment message **920**. In other implementations, the access point **202** can abort operations for analyzing the suitability of the current position of the wireless repeater **210** and switch to the access point mode if the acknowledgment message **920** is not received before the predetermined timeout interval elapses.

After the access point **202** receives the acknowledgment message **920**, the access point **202** switches to the access point mode as depicted in state **924**. The wireless repeater **210** also switches to the client mode as depicted by state **922**. As depicted by the state **924**, the access point **202** also analyses the access point throughput table and the repeater throughput table and determines an access point association table and a repeater association table, as described above with reference to blocks **520-524** of FIG. **6**. The access point **202** transmits (to the wireless repeater **210**) a message **926** comprising the repeater association table. The wireless repeater **210** acknowledges receipt of the repeater association table by transmitting an acknowledgement message **928** to the access point. Finally, the access point **202** transmits an analysis complete message **930** to the wireless repeater **210** to indicate that analysis of the suitability of the current position of the wireless repeater **210** is completed.

It should be understood that FIGS. **1-9** are examples meant to aid in understanding embodiments and should not be used to limit embodiments or limit scope of the claims. Embodiments may perform additional operations, fewer operations, operations in a different order, operations in parallel, and some operations differently. For example, although FIG. **2** and FIGS. **5-9** describe the access point **202** analyzing the suitability of the current position of the wireless repeater and determining whether the client stations **206** and **208** should directly connect to the access point **202** (or should connect to the access point **202** via the wireless repeater **210**), embodiments are not so limited. In other embodiments, the wireless repeater **210** can implement functionality for analyzing the suitability of the current position of the wireless repeater **210** and for determining whether the client stations **206** and **208** should connect to the access point **202** directly or via the wireless repeater **210**. In this embodiment, the access point **202** may determine the access point throughput table as described above and may provide an indication of the access point throughput table to the wireless repeater **210**. The wireless repeater **210**, in turn, may determine and compare the AP-repeater-client throughput with the AP-client throughput. The wireless repeater **210** may also determine and indicate (to the access point **202**) the client stations with which the access point **202** should associate and the client stations with which the wireless repeater **210** should associate. Furthermore, in some implementations, functionality for analyzing the suitability of the current position of the wireless repeater **210** and for determining whether the client stations **206** and **208** should connect to the access point **202** directly or via the wireless repeater **210** may be implemented on a standalone network maintenance unit. The network maintenance unit can

receive an indication of the access point throughput table from the access point **202** and an indication of the repeater throughput table from the wireless repeater **210** and can accordingly determine the access point association table and the repeater association table (similarly as was described above).

Although not described with reference to FIGS. **5-9**, in some implementations, in response to determining that the AP-repeater-client throughput exceeds the AP-client throughput, the repeater position analysis unit **204** of the access point **202** can determine whether the AP-repeater-client throughput also exceeds the predetermined throughput threshold to determine whether the current position of the wireless repeater **210** satisfies performance requirements, as described above with reference to FIGS. **3-4**. If it is determined that at its current position the wireless repeater **210** satisfies performance requirements associated with the client station, the repeater position analysis unit **204** can indicate success of the current position of the wireless repeater **210** with respect to the client station. Otherwise, the repeater position analysis unit **204** can indicate failure of the current position of the wireless repeater **210** with respect to the client station. In other implementations, however, the repeater position analysis unit **212** of the wireless repeater **210** can execute operations described above with reference to FIGS. **3-4** to determine the suitability of the current position of the wireless repeater **210** with respect to each of the client stations.

Furthermore, in some implementations, the repeater position analysis unit **204** can indicate success/failure of the current position of the wireless repeater **210** with respect to the client stations **206** and **208** using LEDs or a display unit. The success/failure of the current position of the wireless repeater **210** can be displayed on the wireless repeater **210**, the access point **202**, and/or an externally connected computer system/display unit. For example, repeater position analysis unit **204** may not switch on the LED associated with the client station **208** in response to determining that the wireless repeater **210** does not satisfy the performance requirements for the client station **208** (i.e., on determining that both the AP-repeater-client throughput and the AP-client throughput are less than the predetermined throughput threshold). As another example, the repeater position analysis unit **204** can display the address, the AP-repeater-client throughput, and success of the current position of the wireless repeater **210** with respect to the client station **208** on the display unit (e.g., an LCD display), in response to determining that the AP-repeater-client throughput is greater than the AP-client throughput and that the client station **208** should associate with the wireless repeater **210**.

Although FIGS. **1-9** depict the repeater position analysis unit analyzing the suitability of the current position of the wireless repeater with respect to all the client stations in the wireless communication network, embodiments are not so limited. In other embodiments, the repeater position analysis unit may analyze the suitability of the current position of the wireless repeater with respect to only a subset of the client stations in the wireless communication network. For example, with reference to FIG. **1**, the repeater position analysis unit **112** may determine to analyze the suitability of the current position of the wireless repeater **104** with respect to the client station **108** (and not the client station **106**). Furthermore, in some implementations, the repeater position analysis unit **112** can also implement the operations described herein to determine the best position (e.g., in terms of X and Y coordinates, height, orientation) at which to place the wireless repeater **104**. The repeater position analysis unit **112** can determine the AP-repeater-client throughputs associated with



each of the client stations **106** and **108** at different positions of the wireless repeater **104**. The repeater position analysis unit **112** can identify the position of the wireless repeater **104** that yields the best throughput for all the client stations **106** and **108** in the wireless communication network.

Although FIG. 3 depicts the traffic generation unit **114** transmitting one training packet to the client stations **106** and **108** and the access point **102** to determine the repeater-client throughput and the repeater-AP throughput respectively, embodiments are not so limited. In other embodiments, the traffic generation unit **114** can transmit any suitable number of training packets to determine the repeater-client throughput and the repeater-AP throughput. The traffic generation unit **114** can transmit multiple training packets over a programmable number of time intervals to guard against variations in PHY rate, PER, and other performance measurements due to attenuation, distortion and other interference effects. The number of time intervals can be determined to maintain an optimal balance between the total time required to analyze the suitability of the current position of the wireless repeater **104** and the accuracy of the wireless repeater **104**. In one implementation, the traffic generation unit **114** can receive an acknowledgement message for each of the transmitted training packets. The performance analysis unit **116** can determine the PHY rate and the PER associated with each of the received acknowledgement messages and can calculate the corresponding repeater-client throughput (or the repeater-AP throughput). The performance analysis unit **116** can calculate an average repeater-client throughput (or an average repeater-AP throughput) over the programmable number of time intervals. In another implementation, the traffic generation unit **114** can receive one acknowledgement message for multiple transmitted training packets (e.g., 1 block acknowledgement message per 10 transmitted training packets). Based on the number of block acknowledgement messages received, the performance analysis unit **116** can calculate the repeater-client throughput (and the repeater-AP throughput) or the average repeater-client throughput (and the average repeater-AP throughput). The performance analysis unit **116** can then use the calculated throughput values to determine the suitability of the current position of the wireless repeater **104**, as described with reference to FIGS. 3-4.

Embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a “circuit,” “module” or “system.” Furthermore, embodiments of the inventive subject matter may take the form of a computer program product embodied in any tangible medium of expression having computer usable program code embodied in the medium. The described embodiments may be provided as a computer program product, or software, that may include a machine-readable medium having stored thereon instructions, which may be used to program a computer system (e.g., a personal computer, mobile phone, television set-top box, or other electronic device(s)) to perform a process according to embodiments, whether presently described or not, since every conceivable variation is not enumerated herein. A machine-readable medium includes any mechanism for storing or transmitting information in a form (e.g., software, processing application) readable by a machine (e.g., a computer). A machine-readable medium may be a machine-readable storage medium, or a machine-readable signal medium. A machine-readable storage medium may include, for example, but is not limited to, magnetic storage medium (e.g., floppy diskette); optical storage medium (e.g., CD-ROM); magneto-

optical storage medium; read only memory (ROM); random access memory (RAM); erasable programmable memory (e.g., EPROM and EEPROM); flash memory; or other types of tangible medium suitable for storing electronic instructions. A machine-readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, an electrical, optical, acoustical, other form of propagated signal (e.g., carrier waves, infrared signals, digital signals, etc.). Program code embodied on a machine-readable signal medium may be transmitted using any suitable medium, including, but not limited to, wireline, wireless, optical fiber cable, RF, or other communications medium.

Computer program code for carrying out operations of the embodiments may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the “C” programming language or similar programming languages. The program code may execute entirely on a user’s computer, partly on the user’s computer, as a stand-alone software package, partly on the user’s computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user’s computer through any type of network, including a local area network (LAN), a personal area network (PAN), or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

FIG. 10 is a block diagram of one embodiment of an electronic device **1000** including a mechanism for analyzing the suitability of the position of a wireless repeater in a wireless communication network. In some implementations, the electronic device **1000** may be one of a personal computer (PC), a laptop, a tablet computer, a mobile phone, a television set-top box, a personal digital assistant (PDA), or other electronic systems comprising a WLAN device configured as an access point. In another implementation, the electronic device **1000** can be a standalone WLAN access point configured to establish a WLAN communication link with a wireless repeater and one or more WLAN client devices. In another implementation, the electronic device **1000** may be one of a personal computer (PC), a laptop, a tablet computer, a mobile phone, a television set-top box, a personal digital assistant (PDA), or other electronic systems comprising a WLAN device configured as a wireless repeater. In another implementation, the electronic device **1000** can be a standalone wireless repeater configured to establish a WLAN communication link with an access point and one or more WLAN client devices to extend the range of the access point.

The electronic device **1000** includes a processor unit **1002** (possibly including multiple processors, multiple cores, multiple nodes, and/or implementing multi-threading, etc.). The electronic device **1000** includes a memory unit **1006**. The memory unit **1006** may be system memory (e.g., one or more of cache, SRAM, DRAM, zero capacitor RAM, Twin Transistor RAM, eDRAM, EDO RAM, DDR RAM, EEPROM, NRAM, RRAM, SONOS, PRAM, etc.) or any one or more of the above already described possible realizations of machine-readable media. The electronic device **1000** also includes a bus **1010** (e.g., PCI, ISA, PCI-Express, HyperTransport®, InfiniBand®, NuBus, AHB, AXI, etc.), and network interfaces **1004** that include at least one of a wireless network interface (e.g., a WLAN interface, a Bluetooth® interface, a



WiMAX interface, a ZigBee® interface, a Wireless USB interface, etc.) and a wired network interface (e.g., an Ethernet interface, etc.).

The electronic device **1000** also includes a repeater position analysis unit **1008**. The repeater position analysis unit **1008** comprises a traffic generation unit **1012** and a performance analysis unit **1014**. The repeater position analysis unit **1008** can implement operations described above with reference to FIG. **1** and FIGS. **3-4**, when the electronic device **1000** comprises a wireless repeater configured for analyzing the suitability of the position of the wireless repeater. The repeater position analysis unit **1008** can implement operations described above with reference to FIGS. **2, 5, 6, and 9**, when the electronic device **1000** comprises an access point configured for analyzing the suitability of the position of the wireless repeater. When the electronic device **1000** comprises the access point, the wireless repeater (which may also be implemented as the electronic device **1000** of FIG. **10**) can implement operations described above with reference to FIGS. **7-9**. Any one of these functionalities may be partially (or entirely) implemented in hardware and/or on the processor unit **1002**. For example, the functionality may be implemented with an application specific integrated circuit, in logic implemented in the processor unit **1002**, in a co-processor on a peripheral device or card, etc. Further, realizations may include fewer or additional components not illustrated in FIG. **10** (e.g., video cards, audio cards, additional network interfaces, peripheral devices, etc.). The processor unit **1002**, the memory unit **1006**, and the network interfaces **1006** are coupled to the bus **1010**. Although illustrated as being coupled to the bus **1010**, the memory unit **1006** may be coupled to the processor unit **1002**.

While the embodiments are described with reference to various implementations and exploitations, it will be understood that these embodiments are illustrative and that the scope of the inventive subject matter is not limited to them. In general, techniques for placement of wireless repeaters in a wireless communication network as described herein may be implemented with facilities consistent with any hardware system or hardware systems. Many variations, modifications, additions, and improvements are possible.

Plural instances may be provided for components, operations, or structures described herein as a single instance. Finally, boundaries between various components, operations, and data stores are somewhat arbitrary, and particular operations are illustrated in the context of specific illustrative configurations. Other allocations of functionality are envisioned and may fall within the scope of the inventive subject matter. In general, structures and functionality presented as separate components in the exemplary configurations may be implemented as a combined structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements may fall within the scope of the inventive subject matter.

What is claimed is:

**1.** A method comprising:

determining, at a wireless repeater, a repeater-to-access point (repeater-AP) throughput associated with a first communication link between the wireless repeater and an access point associated with a wireless communication network based, at least in part, on a performance measurement for a first plurality of training packets transmitted between the wireless repeater and the access point;  
for a client station associated with the wireless communication network,

determining, at the wireless repeater, a repeater-client throughput associated with a second communication link between the wireless repeater and the client station based, at least in part, on a performance measurement for a second plurality of training packets transmitted between the wireless repeater and the client station;

determining an AP-repeater-client throughput between the access point and the client station via the wireless repeater, the AP-repeater-client throughput based, at least in part, on a minimum throughput value associated with the repeater-AP throughput and the repeater-client throughput; and

indicating whether a current position of the wireless repeater can meet a predetermined performance requirement with respect to the client station based, at least in part, on whether the AP-repeater-client throughput is greater than or equal to the predetermined throughput threshold.

**2.** The method of claim **1**, wherein determining the repeater-AP throughput comprises:

transmitting the first plurality of training packets from the wireless repeater to the access point;

receiving an acknowledgement message from the access point in response to transmitting the first plurality of training packets from the wireless repeater to the access point;

analyzing the acknowledgement message to determine the performance measurement associated with the first communication link; and

determining the repeater-AP throughput based, at least in part, on the performance measurement associated with the first communication link.

**3.** The method of claim **2**, wherein the performance measurement comprises one or more of:

a data rate associated with the acknowledgement message received from the access point,

a packet error rate associated with the acknowledgement message and

a packet overhead associated with the first plurality of training packets and the message.

**4.** The method of claim **2**, wherein determining the repeater-AP throughput based, at least in part, on the performance measurement associated with the first communication link comprises determining a goodput associated with the first communication link based, at least in part, on:

a data rate associated with the acknowledgement message received from the access point,

a packet error rate associated with the acknowledgement message, and

a packet overhead associated with the first plurality of training packets and the acknowledgement message.

**5.** The method of claim **1**, wherein determining the repeater-AP throughput comprises:

transmitting the first plurality of training packets from the wireless repeater to the access point within a predetermined number of time intervals;

receiving a plurality of acknowledgement messages from the access point in response to transmitting the first plurality of training packets from the wireless repeater to the access point within the predetermined number of time intervals;

for each of the plurality of acknowledgement messages, analyzing the acknowledgement messages to determine a performance measurement associated with the first communication link;



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determining an intermediate throughput associated with the first communication link based, at least in part, on the or more performance measurements associated with the first communication link between the wireless repeater and the access point; and

determining an average of the intermediate throughputs determined for the plurality of acknowledgement messages to yield the repeater-AP throughput.

6. The method of claim 1, wherein determining the repeater-client throughput comprises:

transmitting the second plurality of training packets from the wireless repeater to the client station;

receiving an acknowledgement message from the client station in response to transmitting the second plurality of training packets from the wireless repeater to the client station;

analyzing the acknowledgement message to determine the performance measurement associated with the second communication link; and

determining the repeater-client throughput based, at least in part, on the performance measurement associated with the second communication link.

7. The method of claim 1, wherein determining the AP-repeater-client throughput comprises:

calculating a product of the repeater-AP throughput and the repeater-client throughput;

calculating a sum of the repeater-AP throughput and the repeater-client throughput; and

dividing the calculated product by the calculated sum to determine the AP-repeater-client throughput.

8. The method of claim 1, wherein determining the AP-repeater-client throughput comprises:

determining the minimum throughput value from between with the repeater-AP throughput and the repeater-client throughput; and

multiplying the determined minimum throughput value by a predetermined scale factor to yield the AP-repeater-client throughput.

9. A method comprising

determining, at an access point, an access point-to-repeater (AP-repeater) throughput associated with a first communication link between the access point and a wireless repeater associated with a wireless communication network based, at least in part, on a performance measurement for a first plurality of training packets transmitted between the access point and the wireless repeater;

determining, at the access point, an AP-client throughput associated with a direct communication link between the access point a client station based at least in part, on a performance measurement for a second plurality of training packets transmitted between the access point and the client station;

determining a repeater-client throughput associated with a second communication link between the wireless repeater and the client station;

determining an AP-repeater-client throughput of a third communication link between the access point and the client station via the wireless repeater, the AP-repeater-client throughput based, at least in part, on the AP-repeater throughput and the repeater-client throughput;

determining whether the AP-repeater-client throughput exceeds the AP-client throughput;

causing the client station to establish the direct communication link with the access point, in response to determining that the AP-repeater-client throughput does not exceed the AP-client throughput; and

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causing the client station to establish the third communication link with the access point via the wireless repeater, in response to determining that the AP-repeater-client throughput exceeds the AP-client throughput.

10. The method of claim 9, further comprising:

receiving, from the wireless repeater at the access point, an indication of the repeater-client throughput.

11. The method of claim 9, wherein determining the AP-repeater throughput comprises:

transmitting the first plurality of training packets from the access point to the wireless repeater;

receiving an acknowledgement message from the wireless repeater in response to transmitting the first plurality of training packets from the access point to the wireless repeater;

analyzing the acknowledgement message to determine the performance measurement associated with the first communication link; and

determining the AP-repeater throughput based, at least in part, on the performance measurement associated with the first communication link.

12. The method of claim 9, wherein determining the AP-client throughput comprises:

transmitting the second plurality of training packets from the access point to the client station;

receiving an acknowledgement message from the client station in response to transmitting the second plurality of training packets from the access point to the client station;

analyzing the acknowledgement message to determine the performance measurement associated with the direct communication link; and

determining the AP-client throughput based, at least in part, on the performance measurement associated with the direct communication link.

13. The method of claim 9, wherein determining whether the AP-repeater-client throughput exceeds the AP-client throughput comprises:

determining whether the AP-repeater-client throughput exceeds the third throughput by a predefined margin.

14. The method of claim 9, wherein causing the client station to establish the third communication link with the access point via the wireless repeater further comprises:

indicating, in a wireless repeater association data structure, that the client station should establish the third communication link with the access point via the wireless repeater in response to determining that the AP-repeater-client throughput exceeds the AP-client throughput; and

providing, from the access point to the wireless repeater, the wireless repeater association data structure to cause the wireless repeater to prevent association with another client station not indicated within the wireless repeater association data structure.

15. The method of claim 9, wherein causing the client station to establish the direct communication link with the access point further comprises:

preventing association of the access point with another client station not indicated within an access point association data structure, wherein the access point association data structure comprises an indication of client stations that should establish the direct communication link with the access point; and

associating with the client stations indicated within the access point association data structure.

16. The method of claim 9, wherein determining the repeater-client throughput comprises:



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providing, from the access point to the wireless repeater, a control message to cause the wireless repeater to switch from a client mode to an access point mode;

determining whether an acknowledgement message was received at the access point from the wireless repeater, in response to providing the control message to the wireless repeater;

in response to determining that the acknowledgement message was received from the wireless repeater, causing the access point to switch from the access point mode to the client mode; and

causing the access point configured in the client mode to associate with the wireless repeater configured in the access point mode;

in response to determining that the acknowledgement message was not received from the wireless repeater, determining whether a timeout interval associated with the acknowledgement message is elapsed, wherein the timeout interval indicates a maximum time duration for which the access point waits to receive the acknowledgement message from the wireless repeater;

retransmitting the control message to the wireless repeater, in response to determining that the timeout interval associated with the acknowledgement message is not elapsed; and

aborting operations for analyzing suitability of a current position of the wireless repeater, in response to determining that the timeout interval associated with the acknowledgement message is elapsed.

**17.** The method of claim **9**, wherein in response to determining that the AP-repeater-client throughput exceeds the AP-client throughput, the method further comprises:

determining whether a current position of the wireless repeater can meet a predetermined performance requirement with respect to the client station based, at least in part, on whether the AP-repeater-client throughput is greater than or equal to a predetermined throughput threshold; and

indicating whether the current position of the wireless repeater can meet predetermined performance requirements with respect to the client station.

**18.** A wireless repeater comprising:

a processor;

a network interface coupled with the processor; and

a position analysis unit coupled with the processor and with the network interface, the position analysis unit operable to:

determine a repeater-to-access point (repeater-AP) throughput associated with a first communication link between the wireless repeater and an access point associated with a wireless communication network based, at least in part, on a performance measurement for a first plurality of training packets transmitted between the wireless repeater and the access point;

for a client station associated with the wireless communication network,

determine a repeater-client throughput associated with a second communication link between the wireless repeater and the client station based, at least in part, on a performance measurement for a second plurality of training packets transmitted between the wireless repeater and the client station;

determine an AP-repeater-client throughput between the access point and the client station via the wireless repeater, the AP-repeater-client throughput based, at least in part, on a minimum throughput

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value associated with the repeater-AP throughput and the repeater-client throughput; and

indicate whether a current position of the wireless repeater can meet a predetermined performance requirement with respect to the client station based, at least in part, on whether the AP-repeater-client throughput is greater than or equal to the predetermined throughput threshold.

**19.** The wireless repeater of claim **18**, wherein the position analysis unit operable to determine the repeater-AP throughput further comprises the position analysis unit operable to:

transmit the first plurality of training packets from the wireless repeater to the access point;

receive an acknowledgement message from the access point in response to the position analysis unit transmitting the first plurality of training packets to the access point;

analyze the acknowledgement message to determine the performance measurement associated with the first communication link; and

determine the repeater-AP throughput based, at least in part, on the performance measurement associated with the first communication link.

**20.** The wireless repeater of claim **19**, wherein the performance measurement comprises one or more of a data rate associated with the acknowledgement message received from the access point, a packet error rate associated with the acknowledgement message, and a packet overhead associated with the first plurality of training packets and the acknowledgement message.

**21.** The wireless repeater of claim **18**, wherein the position analysis unit operable to determine the repeater-AP throughput further comprises the position analysis unit operable to:

transmit the first plurality of training packets from the wireless repeater to the access point within a predetermined number of time intervals;

receive a plurality of acknowledgement messages from the access point in response to the position analysis unit transmitting the first plurality of training packets from the wireless repeater to the access point within the predetermined number of time intervals;

for each of the plurality of acknowledgement messages,

analyze the acknowledgement message to determine the performance measurement associated with the first communication link;

determine an intermediate throughput associated with the first communication link based, at least in part, on the performance measurement associated with the first communication link between the wireless repeater and the access point; and

determine an average of the intermediate throughputs determined for the plurality of acknowledgement messages to yield the repeater-AP throughput.

**22.** The wireless repeater of claim **18**, wherein the position analysis unit operable to determine the repeater-client throughput further comprises the position analysis unit operable to:

transmit the second plurality of training packets from the wireless repeater to the client station;

receive an acknowledgement message from the client station in response to the position analysis unit transmitting the second plurality of training packets from the wireless repeater to the client station;

analyze the acknowledgement message to determine the performance measurement associated with the second communication; and



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determine the repeater-client throughput based, at least in part, on the performance measurement associated with the second communication link.

**23.** An access point comprising:

a processor;

a network interface coupled with the processor; and

a position analysis unit coupled with the processor and with the network interface, the position analysis unit operable to:

determine an access point-to-repeater (AP-repeater) throughput associated with a first communication link between the access point and a wireless repeater associated with a wireless communication network;

determine an AP-client throughput associated with a direct communication link between the access point and a client station associated with the wireless communication network;

determine a repeater-client throughput associated with a second communication link between the wireless repeater and the client station;

determine an AP-repeater-client throughput of a third communication link between the access point and the client station via the wireless repeater, the AP-repeater-client throughput based, at least in part, on the AP-repeater throughput and the repeater-client throughput;

determine whether the AP-repeater-client throughput exceeds the AP-client throughput;

cause the client station to establish the direct communication link with the access point, in response to the position analysis unit determining that the AP-repeater-client throughput does not exceed the AP-client throughput; and

cause the client station to establish the third communication link with the access point via the wireless repeater, in response to the position analysis unit determining that the AP-repeater-client throughput exceeds the AP-client throughput.

**24.** The access point of claim **23**, wherein the position analysis unit operable to determine the AP-repeater-client throughput, further comprises the position analysis unit operable to:

provide, to the wireless repeater, a control message to cause the wireless repeater to switch from a client mode to an access point mode;

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determine whether an acknowledgement message was received at the access point from the wireless repeater, in response to the position analysis unit providing the control message to the wireless repeater;

in response to the position analysis unit determining that the acknowledgement message was received from the wireless repeater,

cause the access point to switch from the access point mode to the client mode; and

cause the access point configured in the client mode to associate with the wireless repeater configured in the access point mode;

in response to the position analysis unit determining that the acknowledgement message was not received from the wireless repeater,

determine whether a timeout interval associated with the acknowledgement message is elapsed, wherein the timeout interval indicates a maximum time duration for which the access point waits to receive the acknowledgement message from the wireless repeater;

retransmit the control message to the wireless repeater, in response to the position analysis unit determining that the timeout interval associated with the acknowledgement message is not elapsed; and

abort operations for analyzing suitability of the current position of the wireless repeater, in response to the position analysis unit determining that the timeout interval associated with the acknowledgement message is elapsed.

**25.** The access point of claim **23**, wherein the position analysis unit is further operable to:

in response to the position analysis unit determining that the AP-repeater-client throughput exceeds the AP-client throughput,

indicate, in a wireless repeater association data structure, that the client station should establish the third communication link with the access point via the wireless repeater; and

provide the wireless repeater association data structure to the wireless repeater to cause the wireless repeater to prevent association with at least a subset of other client stations not indicated within the wireless repeater association data structure.

\* \* \* \* \*